Volume 18 Number 6

BULLETIN
of the
AMERICAN ASSOCIATION OF
PETROLEUM GEOLOGISTS

JUNE 1934

NATURAL GAS OCCURRENCES OF GERMANY[1]

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ABSTRACT

The occurrences of natural gas in Germany are closely related to the occurrences of oil. The writer discusses five principal types of gas occurrence. 1. Natural gas occurs in the salt region of northwest Germany. As salt-dome structure is potentially productive of oil and gas, the writer lists 64 Saxon Zechstein salt occurrences. The most important oil fields, which also produce gas, are Wietze-Steinförde, Hänigsen-Nienhagen, Oelheim-Berkhöpen, and Oberg. The principal producing horizons are in the Comanche, Jurassic, and Liassic. Gas does not occur as a "gas cap" above the oil, but the oil itself is rich in gas. 2. Natural gas occurs at Volkenroda in Thuringia in nearly flat or only slightly arched beds. The gas overlies the oil in Middle Zechstein dolomite below the potash deposits. 3. Natural gas occurs in the Pechelbronn oil field in the Rhine Valley graben. There are 13 producing horizons in the sandy Oligocene Pechelbronn beds. 4. Natural gas occurs within the area of the North German coal formations. In most places it is in the Upper Cretaceous overlying the coal-bearing Carboniferous beds. 5. Natural gas occurrences in Quaternary deposits are somewhat difficult to explain satisfactorily.

INTRODUCTION

The occurrence of natural gas in Germany is closely connected with the occurrence of oil.[3] According to the classification of European oil occurrences, the German oil occurrences are arranged in four geological groups.

1. Oil occurrences located in the vicinity of Saxon salt plugs in northwestern Germany
2. Oil occurrences in the Zechstein of Thuringia

[1] Manuscript received, July, 1932, for the Association's symposium on the natural gas resources of the world—a volume whose scope was subsequently restricted to North America. The authors have given permission for its publication in the *Bulletin*.

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[3] See H. Stille and H. Schlüter, "European Oil and Gas Occurrences and Their Relationship to Structural Conditions," this *Bulletin*, p. 736.

3. Oil in the Tertiary deposits of the Rhine Valley graben
4. Peri-Alpine oil occurrences in the Flysch region of the Alps[4]

Natural gas occurrences are connected with all these oil occurrences, although in some cases the quantities of the gas are very small. However, combustible gases, which seem to have no connection or only a very problematic connection with oil occurrences, are also found at some places in Germany. In some cases these gases are utilized in limited quantities for industrial purposes. They are found under various geological conditions, for example, within the area of the German coal formations and in several separate Quaternary regions.

I. NATURAL GAS OCCURRENCES IN SALT REGION OF NORTHWESTERN GERMANY

1. REVIEW OF SALT PLUGS AND SALT ANTICLINES OF NORTHWESTERN GERMANY

The following fields, located within the North German Plain, are the most important producers of oil.

Wietze-Steinförde Hänigsen-Nienhagen	Region of Celle
Oelheim-Berkhöpen Oberg	Region of Peine

Small quantities of oil are produced near Hope, west of Wietze-Steinförde. Moreover, traces of oil have been found in many other places. Horst-Wiphausen yielded commercial quantities of oil for a number of years.

The exploited oil occurrences and the great majority of the oil indications are found in the vicinity of salt plugs. Therefore, these salt plugs must be considered in a review of natural gas occurrences and of the possibilities of further discoveries of such occurrences. Figure 1 and Table I show the salt plugs or anticlinal salt structures which are now known and are mentioned in geological literature. Figure 1 also shows the probable disposition of these salt structures along axes which are generally anticlinal. However, many salt plugs, the presence of which has been determined only by means of geophysical exploration, are not mentioned here, inasmuch as reliable information concerning their presence is not available. In Table I the numbers in parentheses refer to the corresponding numbers in

[4] Group 4 (see *Engler-Höfer*, Vol. II, Pt. 2, Leipzig, 1930) is omitted in the following text, because (1) only a very few oil and gas occurrences are known to exist on German territory in the Alpine foreland depression, and (2) it is better to consider this region in connection with the sub-Carpathian occurrences, because from a geological standpoint it forms a western extension of this sub-Carpathian area.

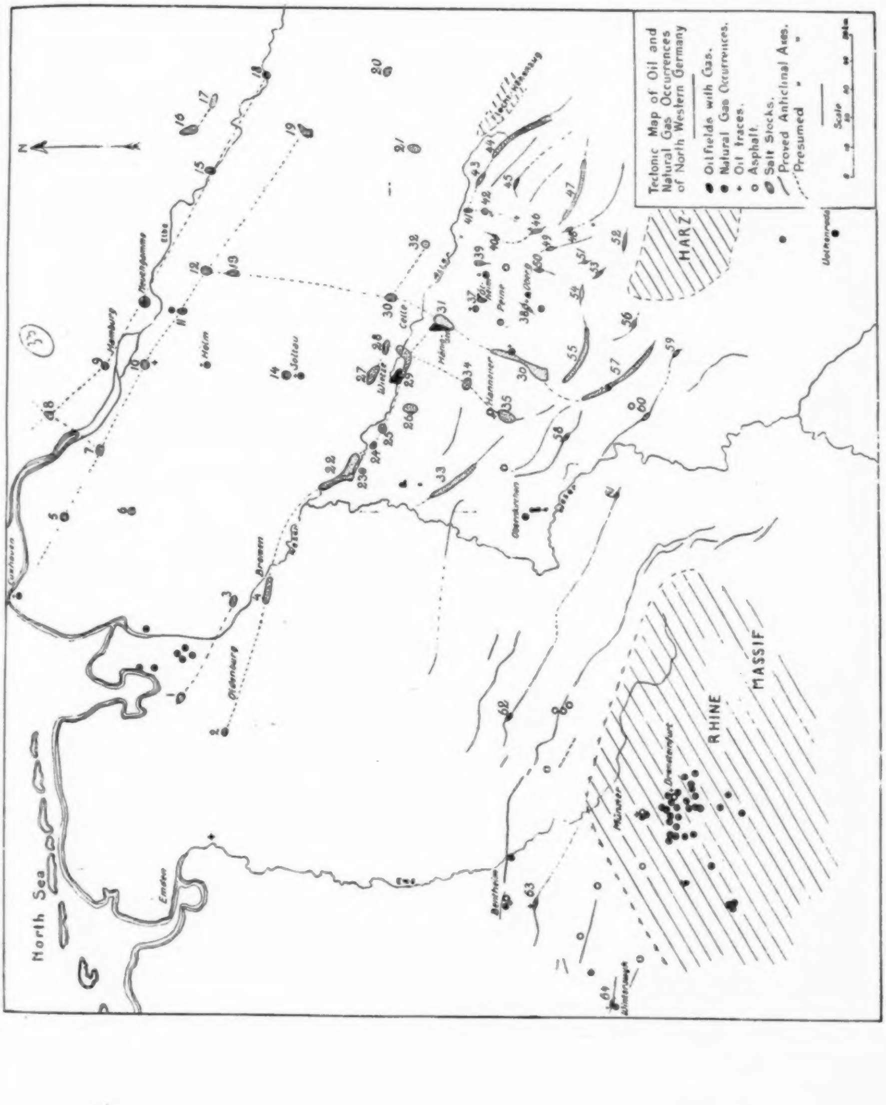

FIG. 1.—Tectonic map of oil and natural gas occurrences in northwestern Germany.

the Bibliography; the serial numbers, 1–64, to corresponding numbers in Figure 1.

TABLE I

SAXON ZECHSTEIN SALT OCCURRENCES IN NORTHWESTERN GERMANY

(See also Figure 1)

1. Jaderberg	Mentioned by Bentz (5);[a] according to his written communication, salt stock discovered by torsion-balance exploration, and salt found by drilling
2. Zwischennahn	Same as 1
3. Vegesack-Lesum	Salt seems to have been found by drilling
4. Bremen-Delmenhorst	Two old wells found only rock salt; but recently potash also found. See Bentz (5) and Wilckens (38)
5. Westersode near Hemmoor at Lower Elbe	Salt discovered in two wells
6. Estorf	Mentioned by Bentz (5); according to his written communication, salt found in old well
7. Stade	Outcrops and drilling. In addition to salt outcrops, also outcrops of older Zechstein and of Rotliegendes (Lower Permian)
8. Leith-Elmshorn	Same as 7
9. Altona	Salt found by drilling according to Fulda (11)
10. Sottorf	Salt found by drilling. See Fulda (11) and Werner (35)
11. Bahlburg	Salt found by drilling
12. Lüneburg	Outcrops of Zechstein gypsum. Salt has been produced since early part of Middle Ages from waters of saline springs
13. Kolkhagen	Salt found by drilling. See Dammer (6)
14. Soltau	Salt found by drilling. See Stille (27)
15. Darchau-Kl. Kühren	Salt found by drilling
16. Lubtheen	Abandoned potash mine
17. Conow	Abandoned potash mine
18. Lenzen	Salt found by drilling
19. Wustrow	Abandoned potash mine
20. Calbe	See Bentz (4)
21. Zicherie	Salt found by drilling. See Keilhack (15)
22. Ahnebergen-Haüslingen	Abandoned potash mine
23. Rethem	Discovered by drilling. See Stille (27) and Fulda (10)
24. Eilte	Discovered by drilling. See Stille (27) and Fulda (10)
25. Gilten	Abandoned potash mine
26. Hope	Abandoned potash mine
27. Meissendorf	Discovered by drilling and partly delineated by geophysical measurements. See Fulda (10) and Schmidt (22)
28. Wolthausen	Discovered geophysically by means of torsion balance and seismic measurements. See Schmidt (22, 23)
29. Wietze-Hambühren	Abandoned potash mine. Delineated by drilling, landslides, and geophysical measurements. See Werner (36) and Schmidt (22,23)
30. Höfer-Habighorst	Rock salt mine. Delineated by drilling
31. Hänigsen-Wathlingen	Potash mine. Western limits determined by drilling
32. Wesendorf	Geophysical explorations by means of torsion balance and electrical measurements. Many landslides. See Werner (36)
33. Steinhuder Meer axis	Tested by drilling and mines. See Stille (27) and Albrecht (2)
34. Iseenhagen	According to Bentz (written communication), salt stock was discovered by torsion-balance operations
35. Benthe	Potash mine. Extent determined by Stille (27) according to outcrops and drilling data

[a] Numbers in parentheses refer to Bibliography at end of article.

36. Sarstedt-Sehnde	Several potash mines
37. Oedesse-Berkhöpen	Abandoned potash mine. See Stoller (30)
38. Oelsburg-Mölme	Potash mine. See Beck (3) and Herrmann (13)
39. Didderse-Rolfsbüttel	Salt found by drilling. See Stille (27) and Woldstedt (40)
40. Abbesbüttel	Zechstein found by drilling? See Woldstedt (40)
41. Weyhausen	Salt found by drilling. See Stille (27) and Fulda (10)
42. Ehmen	Abandoned potash mine
43. Rothenfelde-Hehlingen	Abandoned potash mine
44. Upper Aller Valley (Burbach salt line)	Potash mine
45. Dorm	Potash mine
46. Kl. Schöppenstedt	Salt was found in old well. See Woldstedt (40)
47. Asse	Abandoned potash mine in Asse anticline
48. Hedwigsburg	Abandoned potash mine
49. Thiede	Abandoned potash mine
50. Alvesse	Gypsum (probably Zechstein) found in drilling under Tertiary deposits. See Woldstedt (40)
51. Flachstöckheim	Abandoned potash mine
52. Harlyberg	Abandoned potash mine in crest of anticline
53. Salzgitter	Potash mine, not exploited
54. Osterlinde	Salt was found by drilling. See Fulda (10)
55. Forest of Hildesheim	Potash mine in crest of Hildesheim anticline
56. Rhüden	Abandoned potash mine in crest of Rhüden anticline
57. Leinetal	Potash mine in crest of Leinetal anticline; partly abandoned
58. Brüninghausen	Salt found by drilling
59. Vogelbeck	Abandoned potash mine in crest of Vogelbeck anticline (Elfas axis)
60. Elfas	Salt found by drilling in crest of Elfas anticline (Elfas axis)
61. Pyrmont	Salt found by drilling in crest of Pyrmont anticline (Pyrmont axis)
62. Piesberg	Salt found by drilling in crest of Piesberg anticline
63. Ochtrup	Salt found by drilling in crest of Ochtrup anticline
64. Winterswyk	Salt found by drilling in crest of Winterswyk anticline

Natural gas generally accompanies the oil occurrences. However, "gas caps," as they commonly occur in the American oil fields, have not been found. This is probably due mainly to the small size of the occurrences, and partly to the fact that it was fairly easy for the gas to escape.

In Table II are shown, according to Herrmann (13), the four principal oil-bearing zones of the Saxon region, which also yield gas with oil.

TABLE II

	Wietze	*Nienhagen*	*Oelheim*	*Oberg*
Comanche (Valendis and Wealden)	Heavy oil deposit of upper horizon (Scholle) (Wealden)	Principal oil deposit in Forstort Brand (heavy oil in Valendis)	Principal oil deposit in Oelheim (heavy oil in Valendis)	Small oil deposit (heavy oil in Wealden).
Jurassic (Upper Dogger)	Heavy oil of upper horizon (Scholle) (Wealden)	Productive in the Thekla field (paraffinous oil)	Drilled through during 1928 at Berkhöpen (Parkinsonian beds)	Traces in *Macrocephalas* beds

Jurassic (Lower Dogger)	Lacking	Small	Small	Principal deposit (light oil)
Lower Liassic (Rheatic)	Light oil deposit in lower horizon (Scholle)	Light oil deposit	Drilled through during 1929 at Berkhöpen	Oil traces and salt water

Herrmann is of the opinion that these four oil-bearing zones occupy the same stratigraphic position in all parts of the region, inasmuch as they are everywhere sandstones, which are surrounded and covered by clays, marls, and shaly clays of the very thick marine clayey formations of the Liassic, Dogger, and Comanche periods, each of which has a thickness of several hundred meters.

2. NATURAL GAS IN THE OIL-BEARING REGION OF WIETZE-STEINFÖRDE

Only meager data concerning the gas content and the chemical composition of the gas in the oil-bearing region of Wietze-Steinförde are available. The fact that these gases have been often observed is clearly proved by Table No. 4 in an article by Kraiss (17) on the oil-bearing region of Wietze. Kraiss states:

> There are at present (1916) no wells from which oil flows naturally, although until recently important quantities of gas were encountered in this region.

A small part of this gas is now utilized by local industrial undertakings.

3. NATURAL GAS IN THE OIL-BEARING REGION OF HÄNIGSEN-NIENHAGEN

Stoller (29) reports on the occurrences of gas and its utilization in the Hänigsen-Nienhagen oil field. The heavy, viscous dark green oil, with only a small benzine content and no asphalt, which comes from the best producing zone of this region, the sandy Valendis (Comanche) beds, contains considerable quantities of gas. The gas contains some sulphuretted hydrogen. A well drilled in 1911 yielded enough gas to drive a combustion motor and to heat a boiler installation, et cetera, for several years. Further development after the war, particularly after 1922, increased production of oil and simultaneously the production of gas. The Elwerath mining company is endeavoring to collect the natural gas escaping from several flowing wells and to utilize it. By means of special installations it is now possible to secure the gas from all of the wells simultaneously with the production of crude oil. The gas, obtained in the manner just described, is then treated by the Bergeat method to secure the light benzine vapors and then utilized for heating, mechanical, and chemical purposes.

Analyses of the gas made by the Gas Institute of the Technical High School at Carlsruhe are shown in percentages as follows.

Constituents	*Sample* I	II
CH	96.03	95.95
C_mH_n	0.70	0.80
CO	1.00	1.00
CO_2	0.40	0.50
O_2	0.80	0.60
N_2	1.07	1.17
H_2	Traces	Traces

The heat of combustion of the gas tested in a Junkers calorimeter averaged 9,970 WE/cubic meter at 0° Celsius and an atmospheric pressure of 760 millimeters.

Analyses show that the chemical composition of the gas, even from the same well, is subject to small daily variations. Stockfisch (28) discovered traces of helium in one of the gas samples.

4. NATURAL GAS IN OIL-BEARING REGION OF OELHEIM-BERKHÖPEN

Natural gas occurs in the field at Oelheim-Berkhöpen (Stoller, 30). Further data have not been published. In the recently discovered region of Berkhöpen, considerable quantities of gas are encountered and several of the wells flow naturally with a pressure of about 20 atmospheres.

5. NATURAL GAS IN OIL-BEARING REGION OF OBERG

The oil occurrence of Oberg is described by Herrmann (13). According to present knowledge, the oil completely fills the reservoir rocks. Therefore, it seems that there is no "gas cap" within the oil-bearing bed, though the oil itself is rich in gas. Gas from the producing wells is separated from the oil during the lifting process, and is utilized for the heating of steam boilers. A gas sample taken from Ebag well No. 44 had the following chemical composition.

	Per Cent
Methane	82.0
Ethane and/or its homologues	7.0
Ethylene	0.5
Carbon dioxide	0.1
Oxygen	0.4
Nitrogen and rare gases	10.0
Rare gases: Argon	0.09
Helium	0.0064

6. NATURAL GAS OCCURRENCE OF NEUENGAMME

At Neuengamme natural gas was discovered in 1910, when the city of Hamburg drilled several deep water wells.

A gas blow-out was encountered at the depth of 249.2 meters

(Middle Oligocene). The gas, mixed with drops of water, escaped under a very high pressure from the three openings in the head of the hollow drill rods (water-flush system). The well was not shut in for half a year and even then the pressure measured 27.9 atmospheres. The temperature of the escaping gas was 10° Celsius, the caloric value was 9,000 WE, and the yield per hour as much as 27,900 cubic meters. Two years later, in 1912, the Senate of Hamburg decided to utilize this gas in the city gas works. Twenty-five thousand meters of natural gas were added daily to the coal gas. In addition 20,000 cubic meters per day were used to heat boilers connected with principal pumping installation at the water works. With use, the pressure and yield began to decrease gradually. In 1919, daily production was only 22,111 cubic meters, with a pressure of 1 atmosphere. Therefore, in 1919, another well was drilled at a distance of 11.5 meters from the first well. This second well reached the gas horizon at a depth of 279 meters, and its yield increased the supply from 20,000 to 100,000 cubic meters per day. Soon afterward the first well was cleaned and its daily output increased to 80,000 cubic meters with a pressure of 5 atmospheres. The pressure of both wells was the same. Later, clay plugs frequently interfered with the flow of gas and the decrease of pressure reduced the yield. These two wells have produced a total of about 300 million cubic meters of gas. In 1928, they yielded 2,000–3,000 cubic meters daily and even now they continue to produce small amounts, but they must be cleaned continuously. Eighteen more wells were drilled in this region without success. Geological studies show that it was by mere chance that the first well was located precisely on the very crest of a slightly arched dome. The gas-producing horizon is a sand bed in Oligocene septarian clays. Gas showings have been found in the same horizon at other places, but gas in considerable quantities was encountered only in the area of the first well. An analysis of a sample of this gas follows.

	Per Cent
CH_4	91.5
C_2H_6	2.1
CO_2	0.3
O_2	1.5
N_2	4.6
H_2	0.0135

According to J. Stoller (29), there is probably a salt plug at depth in the Neuengamme region and this seems to be confirmed by the fact that Neuengamme is located on an alignment of salt plugs to which belong the salt plugs at Darchau and Lenzen in the southeast (15 and 18 of Fig. 1 and Table I), and those at Altona and Elmshorn in

the northwest (9 and 8 of Fig. 1 and Table I). Lower Tertiary formations lie conformably under the septarian clays, and below these the entire Gulf series (Cretaceous) was penetrated by a well drilled to a depth of 1,047 meters. Kraiss (18) considers the possibility of an oil deposit in the Cretaceous formations, from which the gas could have escaped, inasmuch as the gas at Neuengamme is similar to gas in the oil-bearing Cretaceous formations at Heide in Holstein, where it consists mainly of methane (91.5–97.0 per cent). The scarcity of oil showings seems to confirm this suggestion.

Stockfisch (28) describes a small natural-gas occurrence south of Neuengamme, which, however, seems to be indirectly connected with that at Neuengamme. Gas was encountered in the Oldershausen well No. 2 at a depth of 1,000 meters, probably in Tertiary rocks. An analysis follows.

	Per Cent
Methane	50.1
Carbon dioxide	0.2
Oxygen	4.0
Nitrogen	45.0
Rare gases	0.7
Helium	0.011

7. UNIMPORTANT, SCATTERED NATURAL GAS OCCURRENCES

In addition to the five previously mentioned fields, deep test wells have been drilled in many places on the North German Plain, and some of them encountered oil and gas showings; moreover, such oil and gas showings are commonly encountered when drilling for water supplies; they have also been observed in the galleries of North German potash mines.

Although most of these natural-gas occurrences are not commercially important, they are here listed with a few explanatory remarks to assist in future exploration and discovery of oil deposits and of gas-bearing horizons, which are commonly associated.

According to Offermann (21), the Dollbergen well No. 4, located 1.5 kilometers north of Dollbergen, found a soft sandstone zone at a depth of 131.3–135 meters, probably of Oligocene age, which yielded gas and a small quantity of crude oil at a depth of 135 meters.

Many years ago, several wells were drilled near Horst-Wiphausen, east of Oelheim. These wells yielded some oil, which was occasionally used for commercial purposes. At depths ranging from 150 to 250 meters an oil-bearing horizon occurs in clays and shaly clays of Comanche (Gault) age. Natural gas also has been found in many parts of this region, although Stoller (32) mentions gas showings in only one of the well logs.

Gas traces were encountered in Comanche (Wealden) rocks at Schierke-Hämeler Wald, west of Peine, at a depth of 1,200 meters.

Wells were drilled between 1870 and 1890 along the edges of the Sarstedt-Sehnde salt plug near Sehnde, but without encouraging results. A shallow mine was opened in this region, and that is said to have found oil and gas in Comanche (Wealden) rocks.

According to Koenen (16), two wells drilled in 1882 near Hohen-eggelsen, south of Oberg, encountered some oil and gas in the sands and clays 15–18 meters thick, which separate the Wealden from the Valendis deposits (Comanche), and which in this region overlie the Upper Jurassic formations. There probably is some connection between this occurrence and the salt plug at Oelsburg-Mölme, and also the previously mentioned oil field at Oberg.

East of Oelheim, the occurrence of gas in the Einigkeit potash mine near Ehmen should be mentioned. Werner (35) reports that in 1925 a strong gas flow was encountered in the eastern part of the field in horizontal holes, drilled in galleries at depths of 650 and 700 meters.

In the Desdemona potash mine, near Alfeld on Leine River, gas escaping from a net of fissures in carnallite deposits exploded on May 7, 1906; and soon afterward small traces of oil were found at a depth of 670 meters at the contact between compact salt and rock salt (Wigand, 37).

Many traces of oil and gas were observed below a depth of 300 meters in strongly brecciated salt rocks, when sinking the shaft of the Adolfsglück mine near Hope. During the preparatory work for the potash deposits, after the sinking of the mine shaft, fissures, cracks, and hollows filled with either oil or gas were commonly encountered.

Gas showings were found near Holm, south of Hamburg, at a depth of 200 meters, in rocks of Oligocene age.

Several wells drilled near Marbostel, south of Soltau, also encountered gas showings in Oligocene rocks. This gas was characterized by a strong benzine odor. The wells are located on the southern extension of the axis of the Zechstein salt plug at Soltau, which strikes north and south parallel with the Rhine.

Gas traces were found in a well near Cuxhaven, which, according to Gürich (12), reached the oil chalk (Cretaceous) at a depth of about 400 meters.

Unimportant quantities of gas were found, according to Kraiss (18), in the oil chalk at Heide in Holstein, north of Cuxhaven.[6] The gas consisted almost exclusively of methane.

[6] This occurrence is not included in the writers' list, as it is not shown on the map.

Near Falkenburg in Pommerania (not shown on list and map), a gas flow was encountered at a depth of 36 meters in Diluvial deposits, during the drilling of a water well. This occurrence was utilized for several years during the war, for heating and lighting purposes. An analysis of this gas follows.

	Per Cent
Methane	87.4
Heavy hydrocarbons	1.8
Carbon dioxide	1.2
Carbon monoxide	5.1
Oxygen	0.8
Hydrogen	0.8
Nitrogen	2.9

The caloric value was 8,189 calories per cubic meter.

In Westphalia, there are several unimportant gas occurrences which belong to the salt region of northwest Germany. Wegner (34) mentions the following: at Bentheim from Wealden (Comanche) rocks; Rheine, at east of Bentheim, from Gault (Comanche) rocks; at Vreden from rocks of undetermined age; and at Winterswyk from Zechstein formations.

II. NATURAL GAS OCCURRENCE AT VOLKENRODA IN THURINGIA

The previously mentioned oil and gas occurrences can be compared with those in the American Gulf Coast region, but the Volkenroda occurrence, here described, belongs, as outlined elsewhere, to the Appalachian type. It occurs in a region of nearly flat or only slightly arched strata.

In June, 1930, a strong explosion occurred in the potash mine at Volkenroda, caused by the ignition of gas escaping unexpectedly from beds lying below the potash deposits. Shortly afterward, the presence of oil and gas was discovered and this discovery has been developed into the most productive oil source in Germany. In September, 1930, the total production of oil from Wietze, Hönigsen, Oelheim, and Oberg was 98,000 barrels; the production at Volkenroda for the same month was 77,000 barrels. Development of this occurrence was supervised by H. Albrecht, director of the Volkenroda mines, who recently published an article on this subject (1). In 1931, more than 100 coreholes were completed in the mines at Volkenroda-Pöthen, exploring this occurrence. The wells were drilled in the mine at a depth of about 1,000 meters below the surface. From this core-drilling data, the following succession of formations underlying the potash deposits was determined.

		True (Vertical) Thickness in Meters	
Upper Zechstein	older rock salt	27–45	
	basal anhydrite	8–20	
Middle Zechstein (principal dolomite)		34–64	(source of oil and gas)

The oil- and gas-bearing zones are scattered through the entire thickness of the dolomite from top to bottom. In general, gas is encountered first and the oil is found at a greater depth. The dolomite is crossed by diagonal cracks and at places it is finely fissured and laminated. The oil occurs in these transverse cracks. The formations are slightly folded. Albrecht shows that the accumulation of oil is controlled by anticlinal features; the crests of folds contain large quantities of gas. The best yields of oil are obtained from wells located on the relatively steeper flanks of the anticlines. On and near the anticlinal axes the gas pressure is 80 atmospheres and on the flanks in the oil-bearing area it is 20–40 atmospheres. At present 50,000 cubic meters of gas are produced daily, of which 20,000 cubic meters are utilized by the producing company as fuel under boilers, and the remaining 30,000 cubic meters will be transported by a pipe line to other enterprises. Analyses show the following average composition.

	Per Cent
CH_4	54.5
C_2H_6	12.4
C_3H_8	9.0
C_4H_{10}	3.7
C_mN_n	2.2
CO	0.1
CO_2	0.0
O_2	0.1
N_2	18.0

The combustion heat is 10,373 k.cal/m^3 at 15° Celsius and 735 millimeters pressure. The specific gravity is 1.038.

III. NATURAL GAS OCCURRENCE OF UPPER RHINE

Strong gas emanations were observed in the Pechelbronn oil field (Fig. 3) in the region of the Rhine Valley graben (Alsace), but in consequence of a very long exploitation, a considerable part of this gas has already escaped. At present there seem to be only a very few wells, if any, from which the oil is flowing by natural gas pressure. The greater part of the oil is produced at present not in wells, but in mines and galleries. Formerly important quantities of gas were encountered in some of the wells in various horizons of the formations overlying the heavy oil deposits in the vicinity of fractures. The gas and the oil occur in sandy Oligocene beds within clayey formations. In these Pechelbronn beds there is a sequence of 13 oil-bearing hori-

zons, which are also gas-bearing, and from which the gas penetrated through fractures into the overlying formations.

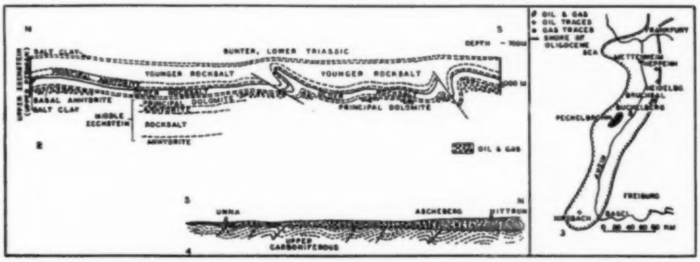

FIG. 2.—Cross section of oil occurrences at Volkenroda in Thuringia. According to Albrecht (1) and Simon (26). Length of section, 4 kilometers.

FIG. 3.—Extension of Oligocene sea in present Upper Rhine region. According to Kauenhowen (14).

FIG. 4.—Schematic geologic cross section of Westphalia gas-bearing region from Unna to Münster. According to Wegner. Length of section, 45 kilometers.

Northeast of Pechelbronn, gas was found in 1900 in a well drilled in the Bavarian Palatinate near Buchelberg, at a depth of 290 meters. The gas escaped from the well with strong eruptions. According to an analysis of Engler, Carlsruhe, quoted by Niels Hviid (20), the chemical composition of the gas is as follows.

	Per Cent
Methane	79.6
Ethane	3.17
Carbonic acid	Traces
Oxygen	2.3
Nitrogen	14.4

IV. NATURAL GAS OCCURRENCES WITHIN AREA OF GERMAN COAL FORMATIONS

In the Province of Westphalia combustible gases were commonly found when boring for coal. These occurrences were described in 1924 by Th. Wegner (34); he mentions more than 70 cases of gas emanations in coal wells. Some of these gas occurrences were utilized for industrial purposes, though in general on a small scale. According to a brief statement recently made by Schmidt (23), a few of these occurrences continue to yield comparatively large quantities of gas.

In the majority of cases the natural gas is in the Upper Cretaceous formations overlying the coal-bearing Carboniferous beds. But even in the Carboniferous beds themselves emanations of gases with a characteristic petroleum odor have been observed in coal wells, not

to mention the common gas emanations in the coal mines. Figure 4 illustrates the geological conditions of this region.

The upper surface of the Carboniferous formations plunges gradually northward under the transgressing Cretaceous series. The most important gas occurrences are near Ascheberg, where particularly strong gas emanations were observed in the Ascheberg well No. 4 and the Dora well No. 17 in the mining district of Hamm. The gas eruption in Ascheberg well No. 4, which occurred in 1904, was so strong that the derrick was blown up and the gas caught fire. The gas was encountered at a depth of 920.5 meters in the transition zone between the Cuvieri and Brongniarti beds (Turonian). After the fire was extinguished, drilling was continued. A second gas eruption took place at the depth of 1,049 meters in Cenomanian rocks. The coal-bearing horizon of the Carboniferous deposits was reached at the depth of 1,139.6 meters. In addition to this occurrence, which was important, if the general conditions in Germany are considered, natural gas was observed in many places in the whole region. The occurrences are so close together that it is impossible to show each of them on the general map.

Unfortunately, accurate analyses of these gases are hardly available, so that it is impossible to decide to what extent this gas is a real oil gas or only a pure coal-mine gas (CH_4). If this gas is pure methane, its presence in the formations would be due simply to the escape of gas from the coal strata. But it seems that this is not everywhere the case and that, in addition to such a simple emission of gas by the coal strata, some chemical processes took place at depth, with the result that oil-like products were formed, yielding regular oil gases characterized by the presence of ethane. This seems to be confirmed by the following average analysis of several samples of gas taken from the Ascheberg well No. 3a.

	Per Cent
Methane	94.1
Ethane	3.1
Heavy hydrocarbons	0.1
Carbon dioxide	0.0
Oxygen	0.5
Nitrogen	2.2

In fact, oil and asphalt also were found within the area of the gas occurrences. Thus, for instance, the presence of oil together with gas was recorded in the Ascheberg well No. 3a and near Drensteinfurt, whereas asphalt was found at Drensteinfurt and south of Münster.

Degenhardt (7) reports that in the coal mines near Bückeburg, in the Oberkirchen mining district, which are exploiting the coal of

the Wealden formations, gas is found in the coal strata as well as in the Wealden shales. The Oberkirchen mine alone yields more than 10,000 cubic meters of gas daily. The gas has the following composition.

	Per Cent
Methane	60.5
Ethane	37.6
Carbon dioxide	2.5

The gas occurs partly in the mines and galleries, partly also in the coal drifts. It comes from the coal-bearing Wealden strata, as well as from the overlying Upper Wealden shales. It is possible that whereas the coal strata yield the regular coal gas (CH_4), the bituminous shales, which are widely developed in the Wealden formations, yield real oil gas.

V. NATURAL GAS OCCURRENCES IN QUATERNARY DEPOSITS

The origin of the gas occurrences within the area of the lower course of Weser River, particularly in Oldenburg, is somewhat problematical. Schütte (25) gives the following analysis of a sample taken from a small occurrence near Struckhausen.

	Per Cent
Methane	70.8
Other hydrocarbons	1.0
Carbon monoxide	1.0
Carbon dioxide	10.0
Oxygen	3.2
Nitrogen	13.9

The upper caloric value was 7,390 calories at 0° Celsius and 760 millimeters pressure. Hitherto it was considered that the origin of this gas is due to the decomposition of recent plant deposits, and, in a general way, this explanation probably corresponds with the facts. This, however, naturally does not exclude the possibility that at least a part of this gas comes from lower oil deposits connected with salt plugs and located around them. This latter opinion seems to prevail at present.

Gas occurrences of a similar kind are known to exist also at several places in Schleswig-Holstein (not shown on the map), for instance, at Apenrade (Stoller, 29), where gas has been encountered in a water well. This gas consisted almost exclusively of methane (92.4 per cent). As the presence of ethane is not mentioned, it is doubtful whether this is an oil gas or a pure marsh gas. Wolff (39) reports that near Schottsbüll in Schleswig-Holstein, another gas occurrence was discovered in Quaternary formations and that this gas flow had lasted

for several months. Farther north, small gas occurrences have been found in Dutch and Danish territory.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 6 (JUNE, 1934), PP. 736-745, 1 FIG.

EUROPEAN OIL AND GAS OCCURRENCES AND THEIR RELATIONSHIP TO STRUCTURAL CONDITIONS[1]

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ABSTRACT

The oil and gas occurrences of Europe are here classified, on the basis of structural conditions, into Alpine and extra-Alpine groups. Alpine Europe was affected by recent mountain-building forces. It is characterized by intense folding and overthrust structure. Extra-Alpine Europe formed the framework against which the Alpine folds were directed. The extra-Alpine region had been subjected to earlier movements (Upper Paleozoic, Silurian, and pre-Cambrian), and had become so solidified that it was not affected by the more recent movements creating the Alpine chains.

The classification presented is based on one proposed by A. Moos. The Alpine region contains (1) peri-Alpine occurrences in the exterior border of the Alpine folds, and (2) intra-Alpine occurrences in the interior parts of the Alpine depression. The extra-Alpine region contains occurrences of the (1) Saxon, (2) Rhine Valley, and (3) Appalachian type. Most of the occurrences belong to the peri-Alpine type, producing 97 per cent of European crude oil or about 9 per cent of the world's production.

This review of European oil and gas occurrences and their relation to structural conditions is based on the contrast existing between the Alpine and the extra-Alpine provinces of Europe. Alpine Europe (Neo-Europe) includes those regions of the continent which were affected by recent mountain-building processes so as to produce an "Alpine structural type," that is, those which are characterized by intense asymmetrical folds, overthrust structures, and other forms of strong recent tectonic movements. Extra-Alpine Europe formed the frame-work for this strongly folded Alpine zone, and against this frame-work the Alpine folds were directed. These are regions which had been affected by older movements, partly by Variscan deformation in Upper Paleozoic time, partly by Caledonian movements in Silurian time (Paleo-Europe), and also by pre-Cambrian folding and intrusions. These formations had become so much solidified that the more recent orogenic movements, which created the Alpine chains, did not affect them, with the exception of tectonic reactions of the so-called "German type." The latter include small undulations, many

[1] Manuscript received, July, 1932, for the Association's symposium on the natural gas resources of the world—a volume whose scope was subsequently restricted to North America. The authors have given permission for its publication in the *Bulletin*.

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of them faulted, or simple fault-thrusts, such as grabens and horsts. For about 20 years the term "Saxon" has been applied to the "German type" of folding in the extra-Alpine regions.

The classification of the oil- and gas-bearing areas of Europe given in Table I is based on the one proposed by A. Moos.[3]

TABLE I

CLASSIFICATION OF EUROPEAN OIL AND GAS OCCURRENCES

I. Alpine region
   1. Peri-Alpine belt or exterior border zone of Alpine folds
   2. Intra-Alpine belt or interior Alpine depressions filled with Tertiary deposits

II. Extra-Alpine region
   1. Saxon type
   2. Rhine Valley type
   3. Appalachian type

I. ALPINE REGION

1. PERI-ALPINE BELT

The great majority of European oil and gas occurrences are found in the peri-Alpine border zone. The Alpine structure is characterized by the presence of depressed areas, which were formed by tectonic movements in the outer regions of the Alpine chains. Very thick Tertiary formations are found in these outer regions. In the vicinity of the mountain chains, these regions of thick Tertiary deposits are generally folded, but the intensity of this folding decreases according to the distance away from the mountain chains. Most of the oil occurrences of the peri-Alpine belt are located in these depressed border areas; therefore, they may be called foreland depression occurrences. The largest oil and gas fields of Europe lie in these areas and in general they include almost all occurrences which until now have been commercially important.

Caucasus.—In eastern Europe are the large Russian oil occurrences of the Caucasus region. The Caucasus system is continuous with the Alpine system in Europe. In Asia the Caucasus system merges with the Armenian system of trans-Caucasia. The Caucasus region is separated from the latter by a foreland and the folding of the chains is commonly directed toward this foreland located in the south. A foreland depression is also present here. But a similar depression is found north of the Caucasus, where a foreland is also present, and a small part of the Caucasus folds strikes here toward the north. In connection with these geological conditions of the mountains, it can now be understood why peri-Alpine oil occurrences are known to exist here on the north as well on the south of the Caucasus. The oil-

[3] Engler-Höfer, *Das Erdöl*, Vol. II, Pt. 2 (Leipzig, 1930).

bearing region of the Kuban district (Maikop, Ilsk, U.S.S.R.), as well as the fields at Grozny, belong to the northern group, whereas the prolific oil-and gas-bearing areas of the Baku district belong to the southern group. The undeveloped occurrences of oil at Cheleken, on the opposite side of the Caspian Sea, should be included in the Baku zone; whereas, the Kerch occurrences in eastern Crimea should be included in the northern zone. The fields of the Grozny and Kuban districts produce principally oil from rocks of Oligocene and Miocene age. Fields of the Baku region produce oil and gas from rocks of Lower Pliocene age. The average thickness of the Productive series, in the Baku region, is about 1,300 meters. The thickness of this series increases toward the east. The total thickness of Tertiary formations in the Baku region is about 4,000 meters.

Carpathians.—Another group of oil fields, belonging to the peri-Alpine type, is on the east flanks of the Carpathian Mountains, extending from Roumania through Poland and into Czechoslovakia. The more important Roumanian oil fields are in the folded Neogene region, which is a depressed zone and forms the forelands of the southern Carpathians. This zone subsided continuously during Aquitanian, Miocene, and Pliocene time and on it 4,000 meters of Neogene sediments were deposited. During Upper Tertiary time these deposits were strongly folded. The oil and gas deposits of this region are located on diapir folds, in fractures due to the formation of Oligocene and Miocene salt masses and in areas where the folding is less intense, especially simple anticlines, which are highly gas-bearing. The wells produce largely from sandy beds in the Meotic and Dacic formations of Pliocene age.

The oil fields of northern Roumania and particularly those of Poland are located in the Flysch zone at the exterior border of the Carpathians. The beds are intensely folded and some are overthrust. The oil occurrences of northern Roumania, which from a commercial standpoint are not very important, are located on or in front of the overthrust zone, which is nearest the Carpathians.

The tectonic and stratigraphic conditions of these regions are not very clear. Oil and gas are obtained chiefly from Oligocene deposits. Inside of the Flysch zone of Galicia, there are three overthrust units, one above another. From bottom to top they are: (1) the Boryslaw overthrust or the eastern border group, (2) the Central overthrust, and (3) the Magura overthrust.

Oil is found in each of these three overthrusts. The largest Polish oil field is Boryslaw, located at the border of the frontal part of the Boryslaw overthrust and below the front of the Central overthrust.

The oil is found in rocks of Cretaceous, Eocene, and Oligocene age. In the Boryslaw field all the sandstone horizons from the Polanica beds of Oligocene age to the Jamna sandstones of Cretaceous age are oil-bearing. In the foreland of the overthrusts, no petroleum deposits have been found, but a very important gas well has been discovered near Daszawa, which in 1926 produced 36 million cubic meters of gas from Upper Miocene beds.

Along the exterior border of the Carpathians westward from Galicia, oil indications are found at several places in Czechoslovakia. Oil and gas seepages from Lower Eocene deposits near Tarzowka led to the drilling of deep test wells, but the quantity obtained was very small. Strong gas seepages from Eocene beds occur near Hluk, on an anticline.

Northern Alpine border.—At the northern border of the Alps, seepages and showings of oil and gas have been found at several places, but no important production has been obtained. In the Alpine foreland depressions, gas showings were encountered near Wels in Austria, in Miocene Schlier beds. In Germany oil occurs at Tegern Lake in a Cretaceous Flysch zone. Unimportant oil seepages occur in the Flysch along the northern border of the Swiss Alps. In France no oil occurrences of the peri-Alpine type have been found.

Pyrenees.—The Spanish Pyrenees, which are bordered on both sides by foreland depressions, may be considered as an outpost of the Alpine system, similar to the Caucasus system. In the southern part of these mountains, in Catalonia, seepages of oil are found near Broka and Vich, and gas near Broka, both in Eocene beds. In the border regions of the Betic Cordillera a small seepage of oil was found near Conil, during the construction of galleries for sulphur production.

Apennines.—The Italian occurrences in the peri-Alpine zone seem to possess a certain commercial importance, though for the moment they are not well developed. The most important oil occurrences are in the province of Emilia, where small quantities of oil have been produced for a period of years. In the west, oil indications begin south of Voghera in the Province of Pavia, and continue along the Apennines for a distance of 225 kilometers. Most of the oil occurrences are on the northeast flank of the Apennines in the Flysch (Upper Eocene) or in Upper Tertiary beds which lie above the Flysch. In central Italy oil was obtained from Upper Tertiary formations in the Pescara Valley. This region shows low folds and some faults. Lotti states that between the Pescara Valley and the province of Emilia numerous surface oil showings and mud volcanoes are present and that gas seepages are scattered from the Pescara Valley into the

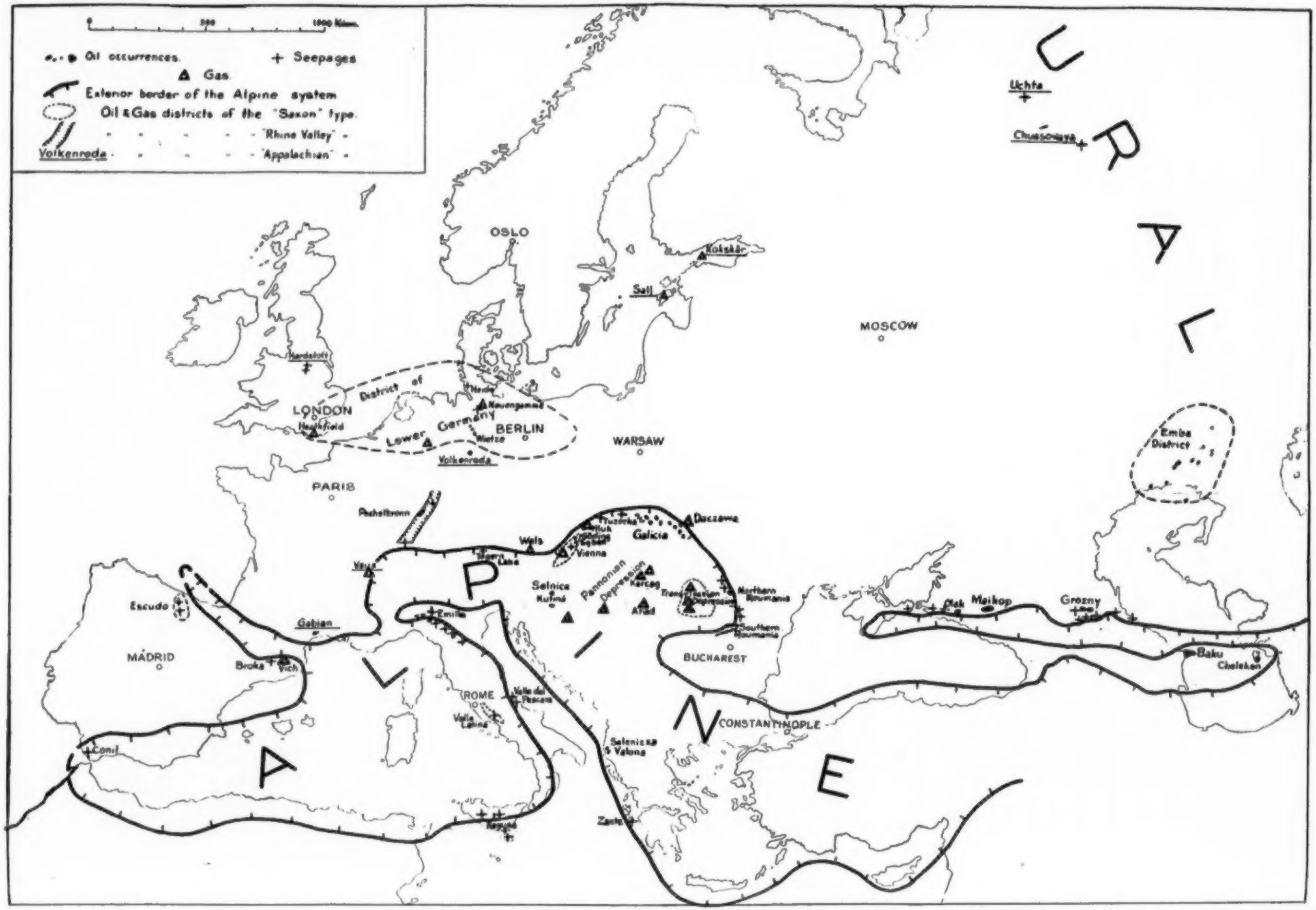

FIG. 1.—Tectonic map of European oil and gas occurrences.

province of Emilia. All the occurrences of oil and gas prove the existence of a real peri-Alpine oil province in Italy. Oil and gas indications in the peri-Alpine zone also occur in Eocene formations in Sicily, and it is obvious that they are closely connected with the well known sulphur deposits of this island.

Albania.—In Albania oil and gas have been encountered recently in several wells drilled through Miocene formations, particularly in the regions of Valona and Selenizza, but the practical results obtained did not meet previous expectations. Farther south, small seepages of oil are known in Pliocene deposits on the island of Xante. These are the most southeasterly occurrences in the peri-Alpine zone of Europe.

2. INTRA-ALPINE BELT

Whereas the exterior Alpine regions contain commercial oil and gas fields, no important oil fields have been discovered inside the Alpine belt of folding in Europe. But there are commercial "dry" gas fields in the intra-Alpine areas.

The hydrocarbon occurrences of the intra-Alpine folded zone are connected either with Tertiary graben zones surrounded by fractures, or with slightly folded Tertiary beds which were deposited in flat depressions within the Alpine area. The Vienna basin and the Valle Latina in central Italy are oil-bearing, Tertiary graben zones located in the folded regions within the Alpine chains. But the Pannonian and the Transylvanian regions belong to the flat basin-like depression zones.

Vienna basin.—The unimportant occurrences at Egbell and Göding in Czechoslovakia are in the northeastern part of the Vienna basin, at a place where the eastern and western border dislocations intersect at a sharp angle. In the Austrian part of the Vienna basin several wells on domes at Lanzendorf and Zisterdorf encountered gas and oil showings in the Sarmatian and Mediterranean formations of Miocene age, as at Egbell and Göding in Czechoslovakia. Some of the older wells, in the immediate vicinity of the city of Vienna, yielded gas for a time.

Valle Latina.—The geological structure of the Valle Latina area in central Italy is similar to that of the Vienna basin. This graben depression extends between the Monti Lepini and the Monte Ernici southeast beyond Rome, and forms a small oil province in which asphalt and gas have been discovered. The graben is filled with slightly folded Miocene beds. On the northeast and on the southeast, the Tertiary beds are surrounded by Cretaceous formations.

Both the Transylvanian and the Pannonian depressions are within the curve of the Carpathian Mountains.

Transylvania basin.—The Transylvanian basin extends over an area of about 20,000 square kilometers, and is surrounded by mountains of crystalline and Mesozoic formations. The basin itself is filled with Upper Tertiary deposits. At the borders of the basin the Tertiary beds are flat or only slightly folded, but toward the center there is a zone of intense folding with diapir structures and uplifted salt masses. In the very center of the basin, there is another slightly folded zone of small dislocations, flat domes, and widely extended synclines. There are two north-south tectonic trends which include most of the domes. Only the western tectonic trend has yielded gas from the sandy Sarmatian beds of Miocene age. In all, 43 domes are known, 6 of which have produced gas, and 21 of which are considered favorable for future gas production. Whereas the Roumanian gases are "wet," the Transylvanian gases are "dry" and consist largely of methane (98–99 per cent). The Transylvanian gas is generally found in several horizons and is everywhere accompanied by iodine and bromine salt water. The production in 1928 was 255 million cubic meters of gas.

Pannonian depression.—The Pannonian depression is also within the curve of the Carpathians, but it is separated from the Transylvanian depression by the crystalline massif of the Bihar Mountains. The basement of the Pannonian depression is a large crystalline massif, upon which the Neogene sediments of this depression were deposited. Böckh and Påvai Vajna have shown that the Tertiary basin of Hungary and Croatia, which previously had not been considered folded, in fact contains numerous parallel folds and that the gas occurrences are closely connected with these tectonic trends. Most of the occurrences are found in sandy Miocene beds. Normally the gas in Hungary occurs absorbed in underground water, from which it escapes freely when the pressure is decreased. The gas is commonly accompanied by flows of very hot salt and iodine water. The gas yield of wells is small, but the gas-bearing area is extensive and may be of commercial importance. Gas in commercial amounts is found at Kutina in Jugoslavia. Production is from beds of Pliocene age, and should be increased by future drilling.

Oil occurrences are very rare within the Pannonian depression; showings of oil were encountered in Pliocene formations near Selnica in Jugoslavia.

II. EXTRA-ALPINE REGION

Occurrences of oil and gas in the extra-Alpine belt of Europe may be divided into three different types: the Saxon type, the Rhine Valley type, and the Appalachian type. The last type could be called the Volkenroda type, because the principal occurrence of this type, discovered in 1931, is near Volkenroda in Thuringia, Germany.

I. SAXON TYPE

The Saxon type comprises those occurrences which are connected with Saxon tectonic forms in areas of faulted folds.

Northwest Germany.—Geological conditions in northwest Germany are typical. Areas of faulted folds formed where the basement formations had been formed previously by old mountain-building processes, so that later orogenic movements resulted only in the formation of small folds or elevated blocks (Schollen). The origin of the latter was due to numerous intersections of fracture systems. The character of the mountain-building process is typically German, in opposition to the intense folding and compressive movements in zones of the Alpine type. Salt domes are found in the vicinity of oil occurrences of the Saxon type. In this respect, oil occurrences of the German type are very similar to those of the American Gulf Coast region; in fact, these Saxon salt plugs have often been compared with those of Louisiana and Texas. In Europe two large oil-bearing regions of the Saxon type are known, namely, the district of north Germany, which is described in detail in a separate article, and the Emba district in southern Russia.

Emba.—Von Bubnoff has called attention to the similarity between the Emba district and north Germany. Just as in northern Germany, Permian salt-bearing beds in the Emba district are covered by Mesozoic rocks of Triassic, Jurassic, and Cretaceous age. Then follow Lower Tertiary formations and—after an interruption in the Lower Sarmatian—Upper Tertiary formations. There are five anticlinal zones, within which a large number of salt domes are known to exist and which are separated from each other by wide synclinal zones. Surface seepages of oil and asphalt are commonly connected with faults that cut through the anticlines. The oil-bearing beds occur largely in rocks of Middle Jurassic and Upper Jurassic age; but some oil has been found in rocks of Permian, Neocomian, and Aptian age. The Emba region produces mainly oil.

Escudo.—The oil occurrences near Escudo in northwestern Spain,

which are not commercial at this time, are found in Mesozoic rocks not far from extrusions of Triassic clay masses, which in northern Spain include plug-like salt massifs. This occurrence seems also to belong to the Saxon type.

2. RHINE VALLEY TYPE

Pechelbronn.—The oil and gas occurrence at Pechelbronn is in the Rhine Valley graben, a structural depression filled with Tertiary deposits. Traces of oil have also been discovered at other localities in this region, namely, near Bruchsal northeast of Pechelbronn and near Hirzbach south of Pechelbronn. The Rhine Valley graben is a large depression filled with younger beds, lying between the Vosges and the Hardt mountains on the west, and the Black Forest and the Oden Forest mountains on the east. Rocks of Jurassic and Triassic age are present beneath the Tertiary rocks. During periods of mountain building the rocks of the Rhine Valley depression were faulted to form several small blocks. The Pechelbronn oil occurs almost exclusively in sandy Oligocene formations, which are called the Pechelbronn beds; but the presence of small quantities of oil has also been reported in Dogger formations. The Pechelbronn area produces oil.

3. APPALACHIAN OR VOLKENRODA TYPE

Oil and gas occurrences connected with gently dipping or slightly folded formations are commonly found in the United States. The classical example is offered by the Appalachian fields. Only a few occurrences showing the same geological conditions are known in Europe.

Volkenroda.—The Volkenroda occurrence should be mentioned first. Development of this field commenced in 1930, and a comparatively good production has been subsequently obtained. At Volkenroda the oil occurs in slightly folded Zechstein beds, and accumulates on anticlines of a special type. The trend of production is shown by the following figures: in August, 1931, 56,000 barrels of oil were produced; and in September, 77,000 barrels. Considerable quantities of gas are encountered which may be used later for commercial purposes.

Hardstoft.—The small occurrence of oil in limestones of Carboniferous age below coal beds near Hardstoft, in England, as well as the occurrences of Chussovaya and Ukhta in Russia, which are still in preliminary stages of exploitation, and localities where oil is found in Permian and Devonian deposits, also belong to the Appalachian type.

Gabian.—According to Gignoux, the oil and gas occurrences of

Gabian, in France, occur on fractured dolomites of the Muschelkalk formation of Triassic age, on an anticline. Thus this occurrence is similar to the Appalachian type, though it should be mentioned that the entire tectonic structure of this locality is much more complex than the structures of the same type previously described.

Vaux.—The geological occurrences of gas near Vaux in the vicinity of Ambérieux, at the outer border of the Swiss Jura Mountains, has not been fully determined. However, the situation seems to be somewhat similar to that observed at Gabian, inasmuch as the gas probably occurs in rocks of Triassic age. Gignoux compares this occurrence with that at Gabian. Thus, though Gabian and Vaux are not far from the outer Alpine border, they may not belong to the peri-Alpine group.

Esthonia.—Traces of oil have been found in Esthonia, and gas has been found in rocks considered by some to occur in the diluvial beds on the island of Kokskaer. It is commonly thought that this gas occurs in older horizons. Doss and Scupin believe that the *Dictyon* shales of Lower Silurian age are the primary source of the gas. As the beds are almost horizontal, this occurrence seems to belong to the Appalachian type.

SUMMARY AND CONCLUSIONS

The foregoing descriptions show that most of the European oil and gas occurrences are of the peri-Alpine type. This group of oil occurrences includes 96.5–97 per cent of the present crude oil production of Europe, which is about 9 per cent of the world's total oil production. At present there are no commercial oil or gas fields of the intra-Alpine type. About 3–3.5 per cent of the European crude oil production is obtained from fields of the extra-Alpine type. The first place is occupied by the Saxon type (Emba region and northern Germany district), then follows the Appalachian type with the recently developed oil field at Volkenroda, and in the last place comes the Rhine Valley type (Pechelbronn). Although the intra-Alpine type has no practical value as far as crude oil production is concerned, it must be mentioned that considerable quantities of gas are obtained in occurrences belonging to this type, particularly in the Transylvanian depression.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 6 (JUNE, 1934), PP. 746-759, 1 FIG.

NATURAL GAS OCCURRENCES IN RUSSIA (U.S.S.R.)[1]

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ABSTRACT

There are 15 known gas fields in European Russia, five of which (Stavropol, Melitopol-Bierdiansk, Astrakhan, Dergachevsky, Sochy) produce only gas; one (Daghestanskie Ogni) is accepted as such for purposes of conservation; and the remaining areas produce both gas and oil (Baku, Grozny, Maikop, Cheleken, trans-Caspia, and Ural-Emba). Taman, Kerch, and Ukhta consist of proved and prospective oil lands.

The most prolific gas-bearing horizons are found in the oil-bearing series of Tertiary age. Fields in southern Russia that produce gas only, are scattered over a large territory extending from the northwestern shore of the Asov Sea and from the vicinity of Stavropol to the northern coast of the Caspian Sea, and even far north of the latter. There are several gas-bearing horizons in the formations of Tertiary age, but only in a single area (Dergachevsky) in this gas-bearing province are the gas pressures and the yield of wells greater.

While gas has been utilized in the oil fields in increasing amounts since 1925, nevertheless the natural gas industry in Russia as a whole does not fully utilize this natural resource.

Occurrences of gas in Asiatic Russia are exceedingly scarce.

INTRODUCTION

Russian literature describing the exploration of gas fields and the utilization of gas is very scarce and since 1918 has not been easily accessible. Current official data on the oil industry do not always include the production of gas.[3]

The Five-Year plan was intended to increase the production of gas in Russia by 1933, calculated in terms of oil, to 2 million tons or to 2,240,254,000 cubic meters (in Russia 700 cubic feet are accepted as the equivalent of 1 pud or 16.679 kilograms of crude oil). The last official Soviet statistics, those for 1926,[4] show by Tables I, II, and IV that only 209,276 tons of gas were produced, or 0.1 of the amount predicated for 1933. However, this aim may not be accomplished,

[1] Manuscript received in 1932, for the Association's symposium on the natural gas resources of the world—a volume whose scope was subsequently restricted to North America. The author has given permission for its publication in the *Bulletin*.

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[3] The writer does not have all the data concerning the production of gas in recent years. But direct personal knowledge, prior to 1917, of almost all gas fields in Russia, excepting Ukhta, Fergana, and Sakhalin, has enabled to him to prepare this paper.

[4] "Annual Report on the Mineral Resources of the U.S.S.R. During the Fiscal Year 1925–1926," *Geological Committee* (Leningrad, 1927).

for, according to latest information,[5] it appears that the principal activity of the industry has been concentrated on the production of cracked gasoline. The total volume of gasoline produced in the area of Grozny in 1931 amounted to 1,981,000 tons, cracked gasoline 276,800 tons, and casing-head gasoline only 84,000 tons. The Grozny region was expected to produce 308,000 tons of gas in 1931, a volume 6 times greater than in 1926. The Baku region produced 588,000 tons of gasoline, including 133,200 tons of cracked gasoline, while the amount of casing-head gasoline is unknown.

According to the Five-Year plan, Russia should attain a crude oil production in 1933 of 47–48 million tons, but in 1931 production was only 23.2 million tons (156,342,900 barrels).[6] The production of gasoline, including casing-head gasoline, increases at a faster rate than does the production of crude oil, indicating tremendous improvements not only in refining activity, but also in the utilization of gas, principally in the Grozny fields.

Until 1918 production statistics consisted only of gas produced at Surakhany in the Baku region, and supplied to neighboring oil fields for fuel. The peak of production in this field was reached in 1907, when 122,295,392 cubic meters or 4,318,797,600 cubic feet were produced. No account has been kept of the gas utilized locally for fuel in the other fields of the Baku district, as well as in those of Grozny, Maikop, and Emba.

The first comprehensive statement of gas utilized in Russia begins with 1926 (Table I).

TABLE I

PRODUCTION OF MEASURED NATURAL GAS IN RUSSIA (CONSUMED GAS ONLY) IN 1,000 CUBIC METERS

Region	*1911*	*1916*	*1924*	*1925*	*1926*
Baku	—	84,000	26,800	87,200	156,200
Grozny	—	16,000	—	37,800	59,300
Daghestankie Ogni	—	—	—	—	11,000
Dergachevsky	—	5,600	—	2,700	1,100
Ural-Emba	—	—	—	—	300
Stavropol	—	5,300	—	—	—
Maikop	—	400	—	—	—
Total	40,892	111,300	26,800	127,700	227,900

In addition to the gas-bearing regions enumerated in Table I,

[5] *Petroleum* (1931), 47; *ibid.* (1932), 10.

[6] "Petroleum Production, 1931," *Foreign Amer. Inst. Min. Met. Eng.* (1932). Figures given in this American tabulation are somewhat less.

seepages of gas have been found in many other localities in Russia. These are briefly described.[7]

GAS FIELDS OF RUSSIA

I. BAKU

The production of natural gas in the various oil fields of the Baku region, calculated in terms of oil and expressed in metric tons, is as follows.

TABLE II

Region	*1913*	*1922*	*1923*	*1924*	*1925*	*1926*	*1927*	*1928*
Balakhany	—	—	—	—	96	601	—	—
Sabunchy	—	—	—	—	—	868	—	—
Ramany	—	—	—	—	—	1,079	—	—
Surakhany	26,342	20,993	19,201	21,950	66,235	97,319	—	—
Bibi-Eibat	—	1,724	2,184	2,672	13,866	43,095	—	—
Binagadi	—	891	1,116	1,294	3,966	8,822	—	—
Total	26,342	23,608	22,501	25,916	84,163	151,784	160,000	124,932(?)

This gas was used as a field fuel under steam boilers and in gas engines, and in domestic stoves, of which there were from 25 to 15 thousand in use between 1924 and 1926. Until 1926 there were, in the Baku district, only two gasoline absorption plants operating with solar oil (Bibi-Eibat and Ramany), and one plant operating with charcoal at Surakhany. According to the Five-Year plan, at least 25 gasoline plants should have been completed by 1927, with an annual production of 180 million cubic meters of natural gasoline.

The most important gas fields of Russia are those found at Surakhany in the Baku district, where the so-called "wiecznyie ogni" (everlasting fires) have been known since antiquity. The shallow gas-bearing horizons extend over an area approximately 5 kilometers long and about 1.5 kilometers wide. To a depth of about 350 meters more than 23 gas-bearing horizons have been encountered, but below this depth oil horizons predominate. The Surakhany and Bibi-Eibat fields yield a large part of their oil production by flowing (gas pressure). Flowing wells occur in many other fields, proving that large quantities of gas accumulated in the oil series, here of Pliocene age.[8] In 1906 gas pressures at the mouth of wells in the Surakhany field

[7] "Natural Resources of Russia," Vol. IV, *Mineral Resources*, No. 39, "Natural Gas" (*Comité Géologique*, Petrograd, 1918).

"Geological—Prospecting Work for Second Five-Year Plan." Material for discussion, April 12–24, 1932. Issue No. 2 (Moscow, 1932), pp. 417–46. The meeting admitted that the gas industry in U.S.S.R. is in a backward stage and that extensive geological and prospecting work must be done in the five-year period of 1933–37.

[8] S. A. Kovalevskij, "Natural Gases of the Baku Region," *Nieft. Khaz.* (Petrol. Ind.) (Moskva, 1930), 18.

ranged from 20 to 29 atmospheres, but after producing for one year had declined to 4 or 5 atmospheres.

In the Baku region, gas was wasted for many years, causing the gas pressure in the old fields to decline rapidly. But in the new fields at Surakhany, Bibi-Eibat, and Binagadi, an attempt is being made to utilize the gas. In all these fields the gas wells are capped.[9] According to Strizow, the annual production of gas in the Baku region may easily be increased to 400 million cubic meters. According to plans in 1929 a carbon-black plant was to be built in the Baku region with a capacity of 141,500 cubic feet of gas per day and an annual carbon-black output of 1,000 tons.

TABLE III

COMPOSITION OF GAS FROM BAKU FIELDS*

	CH_4	C_2H_4	N_2	O_2	CO_2
Bailoff cap	96.28		3.72		
Bibi-Eibat	82.80	1.60	0.90	0.40	14.30
Bibi-Eibat	70.90	2.60	7.40	1.70	17.40
Surakhany	93.22	1.41	0.35	0.40	4.62
Balachany	75.00	1.70	4.70	1.10	17.50
Sabunchy	72.30	0.70	6.80	1.80	18.40

* A. Pois, "Das Erdgas, seine Erschliessung und wirtschaftliche Bedeutung," *Petrol Zeits.* (1917).

In the vicinity of Baku, over the entire Apsheron Peninsula, on Sviatoi Island, and even at the sea bottom, there are numerous gas seepages that cause the mud volcanoes at Boz-Dag, Lok-Batan, Kelany, Baladjary, and other places to erupt violently at times. Southwest and west of the Baku region, gas seeps from mud cones near Adji-Kabul and the town of Shemakha (Marazy), also south of Baku on the coastal plain at the mouth of Kura River, near Saljany, and at Khan-Kishlak.

Gases from some of the mud cones contain as much as 4 per cent heavy hydrocarbons (Boz-Dag). The gases at Marazy contain as much as 45.6 per cent ethane.[10]

2. GROZNY

Recent production of gas in the Grozny district of Russia, calculated in terms of oil and expressed in metric tons, is as follows.

TABLE IV

Fields	*1925*	*1926*	*1927*	*1928*	*1931*
Old Grozny fields	33,288	40,822	—	—	—
New Grozny fields	9,369	16,670	—	—	—
Total	42,657	57,492	84,000	100,801	308,000(?)

[9] *Azerbeidj. Nieft. Khoz.* (1928), 3.

[10] Charitschkoff, *Allg. Oesterr. Chem. u. Techn. Zeits.* (1911), No. 16.

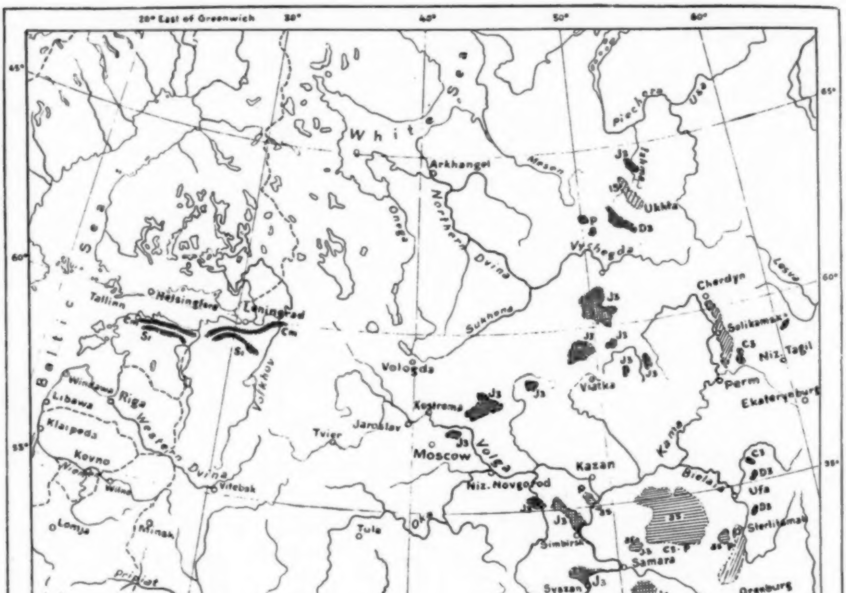
OIL & GAS FIELDS,
BITUMINOUS & ASPHALT ROCKS
IN RUSSIA
Oil & Gas fields.
Nos. 1, 2, 3, 6, 7, 8, 9, 14, 15.
Only Gas fields.
Nos. 3, 4, 10, 11, 12, 13.
Oil fields still prospecting.
Asphalt rock deposits.
Bituminous Shales.
Cm - Cambrian.
S1 - Ordovician.
D3 - Upper Devonian.
C3 - " Carboniferous.
P - Permian
J3 - Upper Jurassic.
N1 - Lower Miocene.
20° East of Greenwich
White Sea
Baltic Sea
Azov Sea
Black Sea
Arkhangel
Leningrad
Helsingfors
Tallinn
Riga
Libawa
Klaipeda
Kovno
Vitebsk
Minsk
Lomza
Rovno
Lwów
Kiev
Kharkov
Poltava
Ekaterinoslav
Odessa
Melitopol
Berdiansk
Bucharest
Danube
Constanza
Sebastopol
Kerch
Novorossiysk
Vologda
Kostroma
Jaroslav
Tvier
Moscow
Tula
Kursk
Voroniev
Niz. Novgorod
Kazan
Simbirsk
Samara
Syzran
Saratov
Zarizyn
Astrakhan
Stavropol
Grozny
Derbent
Tiflis
Batum
Trebizond
Baku
Viatka
Chardyn
Solikamsk
Niz. Tagil
Perm
Ekaterynburg
Ufa
Sterlitamak
Orenburg
Uralsk
Guriev
Dossor
Makat
Volga
Don
Dnieper
Dniester
Prut
Seret
Oka
Kama
Ural
Ilek
Emba
Kuma
Terek
Kura
Northern Dvina
Western Dvina
Vychegda
Onega
Mezen
Piechora
Ukhta
Volkhov
Pripiat

FIG. 1.

In the old oil fields many of the oil-bearing horizons produce gas only on and near the axis of the fold (Mamakaievsky vale). Reservoirs producing only gas occur among the oil horizons in the Lower Sarmation formation, as well as in the *Spaniadontella* and the *Spirialis* beds of Middle Miocene age. In the new fields, oil and gas are obtained principally from the *Spaniadontella* beds. The gas often has a temperature as high as 50°C., and it is these gases that are "wet" and yield large amounts of natural gasoline (as much as 20 per cent of the weight of the gas). The largest gas wells were located in the southeastern sector of the Stary (Old) Grozny area (Solanaia Balka = Salt Creek), some wells producing as much as several million cubic feet per day. Normal casing-head gas contains 82–90 per cent methane, and 2.5–4.8 per cent ethane. An old analysis cited by Beeby Thompson reports 25.4 per cent of heavy hydrocarbons. Analyses cited in the *Nieft. Khoz.* (Petrol. Ind., 1927) report a hydrocarbon content in natural gases as 93–97 per cent. Horizon XIII in the New Grozny field produces with a gas-oil ratio of 20–52 cubic meters of gas to 1 ton of oil; in other sectors of this same field and horizon the ratio is 8–10 cubic meters of gas to 1 ton of oil; Horizon XXI has ratios that range from 17.3 to 38 cubic meters of gas per ton of oil. In the fields of the Old Grozny area the gas-oil ratio averages about 69 cubic meters of gas to a ton of oil.

Until 1925 there were three natural gasoline plants in operation: one an absorption plant at the refinery, and two compression plants, one in each of the Old and the New Grozny fields. According to the Five-Year plan, several new natural gasoline plants were to be erected with a capacity of 40,000 tons of natural gasoline. As a matter of fact, 84,000 tons of natural gasoline were produced in 1931. The writer does not know whether the production statistics given for 1931 comprise light gasoline only, or include the common export product obtained by blending gasoline with ligroine.

3. DAGHESTANSKIE OGNI

Within a zone adjacent to the Caspian shore, between the town of Derbient and the station Kaiakent, gas has been found in many places. Wells prospecting for oil in Berekei have discovered gas and oil in two series: in the Chokrak beds and in the Maikop beds with *Forminifera* beds (of Middle and Lower Miocene age). There are natural seepages near the railway stations at Mamed-Kala and Ogni north of Derbient, and south of Derbient on Rubas-Chai River. In 1929 a well near the station Ogni discovered gas at a depth of 280 meters with an initial closed pressure of 24 atmospheres and an initial

open-flow volume of 180,000–125,000 cubic meters per day. The methane content of this gas ranges from 86.6 to 87.33 per cent, the carbon dioxide content is 13.60 per cent, and nitrogen 0.90 per cent. Gas from this area has been reserved for the operation of a large glass plant. For the present, the dome-like structure near Ogni has been classified as a gas-producing area. More wells are to be drilled on the northwestern extension of this same anticlinal uplift on the coastal plain near Berekei and Kaiakent.

The Ogni gas field is only one of several manifestations of gas fields much more extensive, at present designated as the South Dagestan gas fields. Calculation of gas reserves at those fields is very problematic; for the Ogni field the maximum figure is estimated at 25.2 billion cubic meters, while the minimum figure is given at 248 million cubic meters. The Moscow meeting of April 12–24, 1932, admits that, in spite of such a large possible gas reserve, which according to the meeting might be of great importance not only for Russian industry, but even for the entire world—for the time being even the first series of local chemical "combines" now under construction has not been assured the necessary gas supply.

4. STAVROPOL

Gas was discovered in this district in 1910 while drilling for water. While drilling many subsequent wells for oil, a gas field was discovered near the town of Stavropol that produced gas from several horizons in the Lower Sarmatian formation of Upper Miocene age, and in the *Spaniadontella* and the Chokrak-*Spirialis* beds of Middle Miocene age. The principal gas-bearing horizons are found in the Sarmatian formation. The first zone consists of sands 15–17 feet thick, but the gas-bearing sands of lower zones are not as thick. The first gas-bearing horizon at Stavropol is found at a depth of 90–100 meters. From this depth to a depth of 450 meters eleven less prolific gas-bearing horizons were encountered, principally in strata of Middle Miocene age and even in the underlying Maikop series.

The composition of the gas from the first horizon in the Sarmatian differs in the various wells. One of the analyses showed: CH_4, 37.5 per cent; C_2H_6, 12.25; C_2H_4, 1.2; H_2, 27.25; N_2, 20.3, O_2, 0.8 per cent; and density, 0.581. Gas from another well showed: CH_4, 24.1 per cent; C_nH_{2n}, 0.6; H_2, 1.4; O_2, 13.7; and N_2, 59.6 per cent; with density, 0.880.

Open gas pressure in the Stavropol field did not exceed 0.15 atmosphere, while the velocity of the gas flow was 2–3 cubic meters per second. The capacity of the 8 city wells was 15,000 cubic meters

per day. Later, especially during the civil war of 1919–1922, most of these wells were destroyed. Only three wells are now utilized, two of which supply the flour mill and the third one the city theater.

The gas-bearing area is probably very extensive, for a well drilled about 65 kilometers southeast of Stavropol encountered gas-bearing clays in the Maikop series of Lower Miocene age.

In the second Five-Year plan it has been calculated that the gas reserve might amount to 1,350 million cubic meters; however, the sole basis for this calculation is the large extent of the field, the expected productivity per well, and the number of wells that can be located.

5. MAIKOP

Gas-bearing sands were encountered in various horizons in rocks of Miocene and Oligocene age while prospecting for oil in the fields of Nieftiano-Shirvansk, Khadyzensk, Kaluzskaia, Ilsk, and elsewhere in the Kuban district. Only moderate amounts of gas are utilized in the first two fields. In 1926 a well was completed in the Nieftiano-Shirvansk field that produced 3,415 cubic meters of gas daily, containing 43 cubic centimeters of natural gasoline per 1 cubic meter of gas. An analysis of this gas follows: CH_4 (71.68 per cent), C_2H_6 (11.43), C_nH_{2n} (1.98), and N_2 (4.23). The volume of casing-head gas obtained from 8 wells was 6,000 cubic meters per day; the gas-oil ratio was 27.8 and 21.8 cubic meters of gas per ton of oil.

6 AND 7. TAMAN AND KERCH PENINSULAS

Gas seeps, principally from mud volcanoes, are found at Gnilaia Gora (Tiemriuk) on the Taman Peninsula, and at Bulganak and Chorelek near the town of Kerch. In wells drilled in Tiemriuk and Eisk (Taman) gas-bearing horizons were encountered in the Sarmatian formation. The methane content of the gas is 94.51 per cent at Bulganak, and 72.5 per cent at Tiemriuk. On the Kerch Peninsula, oil- and gas-bearing horizons, some eruptive, have been encountered in the Chokrak series of Middle Eocene age.

Breccias of some of the mud cones on those peninsulas, for example, Shugo near Warenikovskaia on Taman, contain fragments of Lower Cretaceous rocks, while others, as Semigorskaia and Gladkovskaia (east of Taman), are built directly upon rocks of Lower Cretaceous age. Gases from mud cones at Enikale, Bulganak, and Shugo, according to some Russian geologists, differ in their composition from those issuing from oil-bearing horizons. They conclude, therefore, that the former must come from series considerably older.[11]

[11] "Geological and Prospecting Work in the Oil Fields of the Kerch Peninsula in 1926," *Trans. Geol. and Prosp. Serv. of U.S.S.R.*, Fasc. 38 (Leningrad, 1931), pp. 82–83.

8. CHELEKEN ISLAND

Gas on this island occurs only in the oil-bearing horizons found in a series of red marls and sands lying directly beneath the Akchagyl formation, and belonging stratigraphically to the same division of the Pliocene as the oil-bearing horizons at Baku. As late as 1928 there were wells on the western shore of the island at Aligul that periodically discharged oil with violent gas flows.

The mud cones of Cheleken belong to older formations (fossil cones). They are the "necks" of old volcanoes, and usually consist of large fragments of limestone of Jurassic age. Such "necks" are found in groups near Aligul, but these "necks" are not related to the faults that traverse the formation of Pliocene age and the rocks of Oligocene age underlying the former (the so-called formations of the Aligul massif).[12]

9. TRANS-CASPIAN (KRAJ ZAKASPIJSKIJ)

The gas area of trans-Caspia is situated in the vicinity of the town of Chykishlar (district Keimir) on the eastern shore of the Caspian Sea near the Persian boundary. Gas seeps vigorously from the entire series of mud volcanoes and it has been found in wells drilled into formations of post-Pliocene age.

Another such area consists of a group of mud cones, located on the southwestern end of an anticlinal uplift in rocks of Pliocene age at Boia-Dag and Syrtalali. The last (1932) prospecting wells at Nefte-Dag have proved prolific oil- and gas-bearing horizons.

10. MELITOPOL—BIERDIANESK

Gas seepages have been observed throughout a large area in more than 30 localities, while drilling for water. Near the town of Bierdiansk as many as 11 gas-bearing horizons in the Middle Sarmatian series have been found to a depth of 700 feet. Some of those horizons produced gas at high pressures. Throughout this entire area and also northeastward toward the shore of the Caspian Sea the formations of Tertiary age lie nearly horizontally.

11. SOCHY

Gas seeps from formations of Middle Miocene age in many localities along the coast of the Black Sea. Some of this gas is utilized for domestic purposes.

12. ASTRAKHAN

Within the city itself, while drilling for water, two gas-bearing horizons were encountered, at depths of less than 200 meters in

[12] W. Weber, "L'île de Tcheleken," *Reunion Geol. de l'U.R.S.S., 1928, Guide des Excursions* (Leningrad, 1928).

formations (Caspian beds) that are of post-Pliocene and probably even older age.

13. DERGACHEVSKY (MIELNIKOVSKY) REGION

This area is situated north of the Caspian Sea, on the boundary between the former administrative districts of Saratov and Samara. Gas was encountered in many wells drilled since 1906. Accurate analyses of the gas were made in 1926,[13] and in 1928 a systematic investigation of the entire gas-bearing area was undertaken.[14]

One of the wells in this area has furnished gas to a local glass furnace at the rate of 3,000 cubic meters a day, while another well, located 6 kilometers farther south, had an initial production of 31,500 cubic meters of gas per day. This second well is capped to conserve the gas field. Wells drilled 20 kilometers farther north have produced gas. Throughout an area of 300–350 square kilometers there are two very persistent gas-bearing horizons in the Akchagyl formation of Upper Pliocene age at depths of 86–90 meters and 95–100 meters, respectively.

The upper horizon is 1.5 meters thick, and the lower horizon is somewhat thicker. Open-flow pressures of the upper horizon are 8–9 pounds (0.54–0.63 atmosphere) and that of the lower horizon 11.3 pounds (0.77 atmosphere).

In 1926 pressures at the various wells ranged from 0.35 kg./cm.^{2} to 0.58kg./cm.^{2}, a decline of about 67 per cent since 1906. The open-flow volumes of individual wells ranged from 1,350 cubic meters per day to 2,780 cubic meters per day. The total volume from all 8 wells was 13,614 cubic meters per day. The density of the gas ranged from 0.644 to 0.793, and the methane content from 43.6 to 82.9 per cent, that of N_2 and of other rare gases from 16.5 to 55.9 per cent. As the nitrogen content of the gas increases, the radioactivity of the gas increases; the nitrogen content increases with depth of the gas-bearing horizon. The average helium content is considered to be approximately 0.1 per cent (ranging from 0.082 to 0.171 per cent), the helium content increasing as the nitrogen content increases.

For this area, or the Lower Volga, on the basis of very questionable premises for the second Five-Year plan, a reserve of 72 million cubic meters has been calculated.

14. URAL-EMBA

As early as 1916 a gas-bearing horizon was discovered in this region in the Makat field (well No. 102). The horizon occurs in the

[13] *Vestnik du Comité Géologique* (Leningrad, 1928), III, 5.

[14] *Ibid.*, III, 8. Also, *Comité Géol. Matériaux pour la géol. génér. et app.*, Livr. 153 (Leningrad, 1930).

oil-bearing series of Jurassic age. The closed pressure was 8 atmospheres. A second gas well, completed in the southern section of this field in 1926 at a depth of 217 meters (well No. 202), had an initial closed pressure of 16 atmospheres.

Gases from the oil-bearing horizons have a density of 0.539–0.661.

Gas from wells in the Novo-Bogatinsk field (near the town of Guriev) is obtained from the Caspian beds of post-Pliocene age. They contain gasoline vapors. This gas is utilized solely for fuel purposes.

15. UKHTA

In the Piechora basin, natural gas is found as surface seepages and in rocks penetrated by prospecting wells. The methane content of hydrocarbon gases ranges from 78.5 to 99.2 per cent. One well in this basin produces gas periodically at a depth of 490 feet from rocks of Upper Devonian age. This well has a closed pressure of 9.3 atmospheres and an open pressure of 0.67 atmosphere.

In 1928 one of the wells drilled at Chusovskie Gorodki, north of the city of Perm, for the purpose of locating the southern limit of potassium salt deposits near Solikamsk, discovered an oil-bearing horizon below the potassium series. The age of this horizon, according to one geologist, is Permian; according to others it is Upper Carboniferous. In 1930 a well near Cherdyn encountered showings of oil in the same formations at a depth of 557–559 meters. This second locality lies 200 kilometers north of the Solikamsk region. Traces and small flows of gas were encountered in the Chusovskie Gorodki well in the carnallite zone; the methane content of this gas was 33.6 per cent, the hydrogen content 17.4 per cent.

In the vicinity of the cities of Kazan, Samara, and Sterlitamak, all situated in the large Volga basin, asphalt-bearing sands and limestones of Permian and Carboniferous age are common, but there are no indications of gas.

Nor has any gas been observed at any place in central Russia up to the Baltic coast. On the Baltic coast in Estonian territory near Tallinn, upon the island of Koksher, gas was found in glacial formations at a depth of 90 feet. This gas consisted of methane (79 per cent) and hydrogen (20.8 per cent), and flowed with open pressure of about 0.5 atmosphere. Seepages of gas near Riga in Latvia come from peat.

A well drilled in 1925 at Niznij Tagile, on Ural River, for the purpose of investigating a massif of platinum-bearing dunite, encountered gas at a depth of 600 meters, but this flow of gas stopped after two weeks. That gas had the following composition: H_2, 66.5 per cent;

N_2, 20.7 per cent; CH_4, 9.5 per cent; and O_2, 3.3 per cent. No helium gas was found. The gas probably occupied free spaces in the dunite mass, and was a magmatic remnant of light components (H, N, C) in the magnesian-siliceous dunite magma.

Throughout Asiatic Russia occurrences of gas are very infrequent east of the Caspian Sea.

The oil fields of Fergana (Sel-roho, Chimion, and Maili-Sai), producing oil from several thin horizons in a rock series of Eocene age, on the whole yield very little gas. Many of the oil-bearing horizons crop out, and have largely dissipated whatever gas they may have contained.

Natural seepages of gas are found throughout a large area adjacent to the Baikal Sea. They are considered to be of volcanic origin.

Gas is found in the oil-bearing series of Tertiary age in the oil fields on Sakhalin Island; strong hydrocarbon seepages are known on the eastern shore of the island in Nutovo River. The methane content of these gases ranges from 91.0 to 95.5 per cent; the heavier hydrocarbons from 5.1 to 6.8 per cent. The flow of gas from one of the wells approximated 500,000 cubic feet per day.[15]

CONCLUSION

The most prolific gas-producing horizons in Russia are found in series of Pliocene age at Baku and Novo-Bogatinsk; formations of Middle and Lower Miocene age at Grozny, Maikop, and Daghestanskie Ogni; and rocks of Jurassic age in the Ural-Emba region.

The source of gases issuing from mud cones at Kerch, Taman, Kuban, and Chykishlar has not been determined; in some of those regions the gas may have its source in formations that occur beneath the oil-bearing series known there as the Taman, Kuban, and Cheleken.

Throughout an extensive area in southern Russia, from the northern shore of the Asov Sea (in the vicinity of Melitopol and Bierdiansk) and the foothills of the Caucasus (near Stravropol) to the western shore of the Caspian Sea (at Astrakhan), and thence north to Dergachevsky, there is a potential gas-bearing province, unrelated to the oil-fields region that should produce gas principally from the Sarmatian formations of Upper Miocene age, and rocks of Pliocene age, as at Astrakhan and Dergachevsky. The reservoir pressures in this region are usually low. There are several gas-bearing horizons, but

[15] "The Sakhalin Geological and Mineral Expedition of 1925," *Comité Géol. Matériaux*, Livr. 112 (Leningrad, 1927).

low-pressure reservoirs require more wells to maintain deliveries. Only the Dergachevsky region is now commercially important.

Rocks of Paleozoic age contain gas only in the Ukhta region.

Helium occurs in the gas at Dergachevsky. As elsewhere, the quantity of helium increases with increasing amounts of nitrogen. In general, the helium content of gases from rocks of Tertiary age is low (about 0.1 per cent).

Investigation of gas fields and utilization of gas in Russia still leave much to be desired. The Five-Year plan that includes extensive prospecting for oil does not include gas-field investigations.[16] As a matter of fact, large industrial plants, like the glass furnaces in Daghestanskie Ogni and in Dergachevsky, have not been provided with the necessary quantity of gas.[17] No investigations have been undertaken in the great potential gas-producing province of southern Russia since 1917.

The production activities of the U.S.S.R. government are concentrated on increasing the quantity of products for export. Little effort has been made to develop potential sources of energy for local requirements.

On the accompanying map are shown the principal oil-shale areas in Russia: found in formations of Cambrian and Ordovician age in the Baltic province; in formations of Devonian, Upper Carboniferous, and Permian age in the Timan area and the western Ural slope, and also in formations between those of Upper Jurassic and Lower Cretaceous age. The latter form an extensive province traversing eastern Russia from north to south, and curving slightly toward the west; this province delineates accurately the extent of the sea at the "Volgian" stage.

All oil shales are sapropelitic marine formations largely deposited in shallow seas; along the northern coast in seas of Cambro-Ordovician time; and along its eastern coast in seas of several geologic ages in the Timan area and the western Ural slope. In the Caucasus region only the principal occurrences of oil shale of the Maikop series of Lower Miocene age are shown.

Oil shale from the vicinity of Simbirsk yields volatile components up to 40 per cent. The deposits at this locality are calculated at 242 million tons. The oil shales about Sysran yield up to 46 per cent of volatile components and their deposits are estimated at 100 million tons; the oil shales from between the Volga and the Ural yield up to

[16] "Prospecting Borings in U.S.S.R.," *Geol. and Min. Prosp. Serv. of U.S.S.R.* (Moskva, 1930).

[17] *Bull. Geol. and Prosp. Serv.*, Vol. 49, No. 5 (1930), pp. 131–32

49 per cent of volatile components and these deposits have been calculated at 656 million tons. Oil shales from between the rivers Vychegda and Piechora contain up to 63 per cent of volatile components, but it is now impossible to estimate the supply present.

Oil shales are now mined in certain areas (on the Volga, between that river and the Ural, in the vicinity of Leningrad) solely as a source of local fuel; they are nowhere produced in commercial amounts.[18]

[18] The best source of information regarding oil shales is: A. Rosanov, "Les schistes bitumineux de la partie Européenne de l'U.R.S.S.," *Comité Géol. Matériaux*, Livr. 73 (1927), avec 1 carte.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 6 (JUNE, 1934), PP. 760-776, 6 FIGS.

PONTO-CASPIAN AND MEDITERRANEAN TYPES OF OIL DEPOSITS[1]

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ABSTRACT

The oil deposits in the regions of the Black and Caspian seas belong to formations ranging in age from Mesozoic through Upper Tertiary and Lower Quaternary Cenozoic. There are three groups of deposits: (1) deposits related to remnants of old tectonic units raised before the Alpine folding or at its beginning; (2) deposits of the Flysch series, mostly Paleogene, partly Cretaceous; and (3) deposits in Neogene formations. The most important commercial deposits belong to the third group.

The well known large oil deposits in the regions adjacent to the Caspian and Black seas belong to many formations ranging in age from Mesozoic through Upper Tertiary to Lower Quaternary. Some of them form well defined large groups in very rich fields. On the contrary, numerous deposits exist, each of which is somewhat isolated, representing peculiar stratigraphic and tectonic types; such isolated types also occur in the Mediterranean countries, where most of them are Tertiary in age.

It is not very difficult to differentiate geographically between Ponto-Caspian and Mediterranean countries. It is more difficult, however, to try to differentiate geologically because of the development of the Neogene deposits.

The writer thinks that the best definition can be made by taking into consideration only the low basins of the rivers which flow into the three seas. For example, the Ponto-Caspian region extends from the western slopes of the trans-Caspian Ranges to the eastern slopes of the Roumanian Carpathians. The Mediterranean region is the zone immediately adjacent to the Mediterranean basin,—between the seashores and the surrounding mountain ranges.

The oil deposits can be subdivided into three groups.

1. *Deposits related to remnants of old tectonic units raised before the Alpine folding or at the beginning of it.*—Oil seepages and bitumi-

[1] Read by title before the Section on the Geology of Petroleum, of the 16th International Geological Congress, at Washington, D.C., July, 1933. Manuscript received, December 2, 1933.

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nous impregnations exist in many places, where the Mesozoic and older rocks crop out; for example, in schistose but not greatly faulted Mesozoic rocks sufficiently protected from atmospheric agencies.

They form generally isolated marginal areas of great uplifted units, eroded as a rule at the beginning of the Tertiary era. One can not expect to find really important oil deposits in them. As a matter of fact we know only the Mesozoic deposits of real industrial value recognized in the Ural-Emba region on the north side of the Caspian Sea, where the Mesozoic oil-bearing folds are well protected.

2. *Deposits in Flysch series, mostly Paleogene, partly Cretaceous.*—The Flysch that is developed on the margins of large folded uplifts belonging to the Alpine systems forms the principal oil-bearing formation, for example, the Polish Carpathians outside of the Ponto-Caspian region. The producing beds of the Polish Carpathians belong to the Senonian, Eocene, and Oligocene eras. The Flysch of the Roumanian Carpathians, on the contrary, whose eastern slope properly belongs to the Ponto-Caspian region, is not richly petroliferous, being analogous to the small Paleogene deposits in the Mediterranean mountain ranges. Oil seepages and outcrops of impregnated strata are numerous, but really important deposits have not been recognized either in the Caucasian or in the southern Carpathian or Balkan Flysch belts.

Some exceptions to this, and very significant, too, are to be noticed in the Maikop region along the northwestern slopes of the Caucasus Range. It can not yet be said that the Flysch zones of these regions contain any important oil fields. However, producing zones are not impossible along many mountain ranges of the area extending from Turkestan (Ferghana) to northern Africa and to Italy. At any rate our knowledge of the structure of the Flysch belts does not permit us to place very much hope in the preservation of large oil deposits therein. With the possible exception of some places in Egypt, the accumulations in this region may be considered as remnants of large impregnations rather than richly saturated fields with their impervious cover untouched.

3. *Deposits in Neogene formations.*—Most of the large oil-field accumulations are in the Neogene formations. In comparison with them the first two groups of deposits are commercially unimportant. Their formation is due to an intense deposition in the geosynclines which were gradually becoming narrowed through the upheaval of the folds of the Alpine ranges. The rich oil deposits in the Ponto-Caspian countries are Middle and Upper Miocene in age (north Caucasus-Grozny), and Pliocene (Roumania, eastern Caucasus-Baku, trans-

Caspian province-Cheleken). All these zones occupy wide areas with several fields of differing value. Their productivity depends on the degree of saturation of the oil-bearing series and on their preservation due to their recent age.

Besides the principal oil fields, numerous small deposits exist, which are related to nearly all possible stages of the Ponto-Caspian Neogene.

In the Mediterranean countries the most typical oil accumulations, besides the rather scarce occurrences of the Lower Miocene, belong partly to the Middle, but as a rule to the Upper Miocene. They are developed on the margins of the transgressive Miocene deposited on previously eroded uplifts of older rocks.

The literature of petroleum geology on the subjects here discussed includes thousands of titles, especially that on the Russian oil-bearing Tertiary. Reference is made here to only a few of the geologists whose works are of principal interest.[3]

The criteria used to define the principal types of deposits in these regions are here set forth. With the exception of the fields of the Ural-Emba region, there seem to be no sufficiently important deposits that can be considered as a type for the Mesozoic oil zones. For the present, the studies on the Ural-Emba region are not sufficient for summarizing all the characteristics.

Most of the Paleogene oil deposits belong to the widely developed types of Flysch deposits analogous to those in the Polish Carpathians. As a rule, they form only remnants of fields which were formerly rich, but through erosion have lost, except in a few cases, their industrial importance. According to our knowledge, perhaps only the Maikop region in northern Caucasus, well known through the studies of Goubkin,[4] could be considered as a particular type. Other deposits like

[3] Trans-Caspian oil deposits.—Kalitzki, Porfiziev, Weber.

Baku.—Abramovich, Baturin, Golubiatnikov, Goubkin, Kalitzki, Kovalevski, S. Zuber.

Northern Caucasus.—Arkhangelski, Czarnocki, Goubkin, Kalitzki, Kudriavtzev, Prokopov, Vassoievich.

Emba (Ural).—Mironov, Samiatin, Tikhonovich.

Roumania.—J. Athanasiu, Grozescu, M. Kraus, Krejci, Macovei, Mrazec, Murgoci, Preda, Protescu, Pustovka, Popescu-Voitesti, Teisseyre.

Mediterranean countries.—There is no exhaustive literature such as the works of the foregoing authors. Among the authors who have dealt with this subject may be mentioned Anelli, Belluigi, Bonarelli, Coquand, Camerana, Galdi, Dabell, Gignoux, Fossa-Mancini, Höfer, Hume, Lotti, Martelli, E. Novack, Sacco, Salomon-Calvi, A. Wade, S. Zuber.

Much of the literature on the Caucasian subjects is in Russian, some of it with short English summaries, but generally not easily accessible to English readers. On Roumania and on the Mediterranean countries of Europe complete references can be found in the works cited later in this article, especially in the new edition of Höfer's textbook on oil geology.

[4] See I. M. Goubkin, "Tectonics of Southeastern Caucasus and Its Relation to the

those of the Apennine Paleogene (Italy) are limited to isolated units too small to be treated as a particular type.

The deposits of the Caucasian Miocene are known, as are those existing along the northern Persian shores of the Caspian Sea, for their argillaceous character. Among the argillaceous deposits there are a few small fields of no great importance on the shores of the Sea of Azov, which present industrial possibilities.

The Grozny oil fields in northern Caucasus belong to the Middle and Upper Miocene. The oil-bearing folds of this region are among the richest known, but their extremely regular structure requires no special description. The Grozny type may be considered as forming a part of the classic group of regular, although partly asymmetric or even thrust, anticlinal oil deposits that occur in many countries of the world.

Among the Middle Miocene deposits, the oil-bearing zone of Derbent in northeastern Caucasus (Berekei-Kaiakent) should be mentioned. Its structure shows many features common to the Grozny oil fields. Although this oil-bearing belt[5] is not of great importance industrially, its extension should not be ignored.

As already mentioned, the most important Ponto-Caspian oil fields are in the Pliocene formations. These deposits may be classified according to their origin, tectonics, and industrial importance. The later, that is, the Mediterranean type, is to be measured somewhat relatively. Although the oil deposits of this kind, especially in comparison with the Caucasian or Roumanian conditions, may be considered as without any special importance, their value increases because they exist in the countries deprived of their own crude. Thus even poor oil impregnations serve a need and are not to be neglected.

In such a great number of various oil deposits, several types are recognized because of their definite characteristics.

The first is the Baku type. It is classic for its richness and for its stratigraphic and structural characteristics.

The second is the trans-Caspian, or Cheleken type. The most important oil field, once famous, is that of Cheleken Island, now exhausted and forgotten, but because of its tectonic conditions, classified with the principal types, especially as another field of the same type has revealed its richness in a remarkable manner (Nephte-Dagh).

As the third type, characterized by numerous and very rich fields, the Roumanian, near Prahova River, is to be considered. From its location it is called the Prahova type.

Productive Oil Fields," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 5 (May, 1934), pp. 603–71.

[5] Studied repeatedly by Golubiatnikov and Kaitzki.

The fourth group is older, its deposits being Middle and Upper Miocene. It is the Mediterranean type, along the shores of the Mediterranean Sea, and should be treated separately because it shows common characteristics as to its oil distribution and tectonics.

FIG. 1.—Sketch map of main oil-bearing regions in Ponto-Caspian and Mediteranean countries.

The ideal sections included in this article have been constructed in the following manner. The sections across the central sectors of the most characteristic anticlines have been put together in order to show the geometric evolution of the profile from the highly faulted deep parts, through the intrusive bodies of older rocks or of salt, to the gently folded covering strata. The task has been comparatively easy for the Baku type, every uplift of which shows with nearly mathematical exactness the same characteristics. In consequence of this, all the pecularities of the Baku type can be combined graphically and according to the depths of the section, and the different stages of denudation that every oil-bearing fold has passed through can be recognized.

Similar treatment has been possible for the Cheleken type, although the synthesis is more difficult and not so exact as in the former case.

The intrusive salt bodies of the oil-bearing anticlines of the Prahova type show more originality in their structure and this almost prohibits the direct superposition of the sections of the different kinds of Roumanian diapiric folds.

Great difficulties have been found when synthesizing the sections of the Mediterranean type. First, the writer can not publish all the details of his studies, for reasons easy to understand. Furthermore, every oil deposit of this type shows underground conditions that oblige the student to treat the named deposits individually. Notwith-

standing these difficulties, a synthesis is possible, but the section only summarizes several genetic phenomena which the writer has studied in different regions.

I. BAKU TYPE

The oil-bearing folds of the Apsheron Peninsula are developed on the eastern end of the Caucasian Range, where the older strata are covered by the Neogene deposits. Their thickness is very remarkable along the slope of the Great Caucasian Range and, in the Baku region, is influenced by the existence of short, steep folds. The axes of a part of these follow the main direction, that is, the direction of the Great Caucasus, and those of the other units follow the oblique or nearly perpendicular direction. The latter depends on the existence of huge transverse faults affecting the whole Caspian basin. The final effect of the interference of the two different directions of folding gives a net of uplifted zones whose arches surround small, round synclinal blocks.

Generally, the sediments follow each other without any conspicuous discordance, from the Mesozoic to the Upper Pliocene deposits. Except in the margins of several Neogene series, they mark the extreme limits of various transgressions; otherwise no important unconformities are to be seen. This is easy to explain because the east end of the Great Caucasus represents a wide area of continuous sedimentation.

The orogenic movements of all the Apsheron region took place in a tide-like manner and expanded from the main Caucasian upheaval toward the peripheries. The first movements which took place during the Lower Pliocene were very intense only along the old littoral zones of Pliocene lagoons, that is, close to the Caucasus Range, and undulatory only near the peripheric units. The latter underwent orogenic activity much later, that is, at the beginning of the Quaternary. The final folding occurred in paroxysms, giving origin to strange tectonic forms due to the peripheric push and to the reflected movements when the pushed masses were rejected by the rigid and compact round synclinal shields, composed of the Upper Pliocene limestones.

Although no great unconformities exist in the Baku region, the central parts of the anticlines show, as a rule, a lack of normal development of strata, which are much thinner near the crests of the anticlines than on their peripheries. This fact contributed to a previous uplift of the older strata which, because of the lack of a sufficient overburden, were finally disposed in diapiric intrusive bodies analogous to the well known salt plugs, giving to all the uplifts a classic aspect of "reflected buried hills."

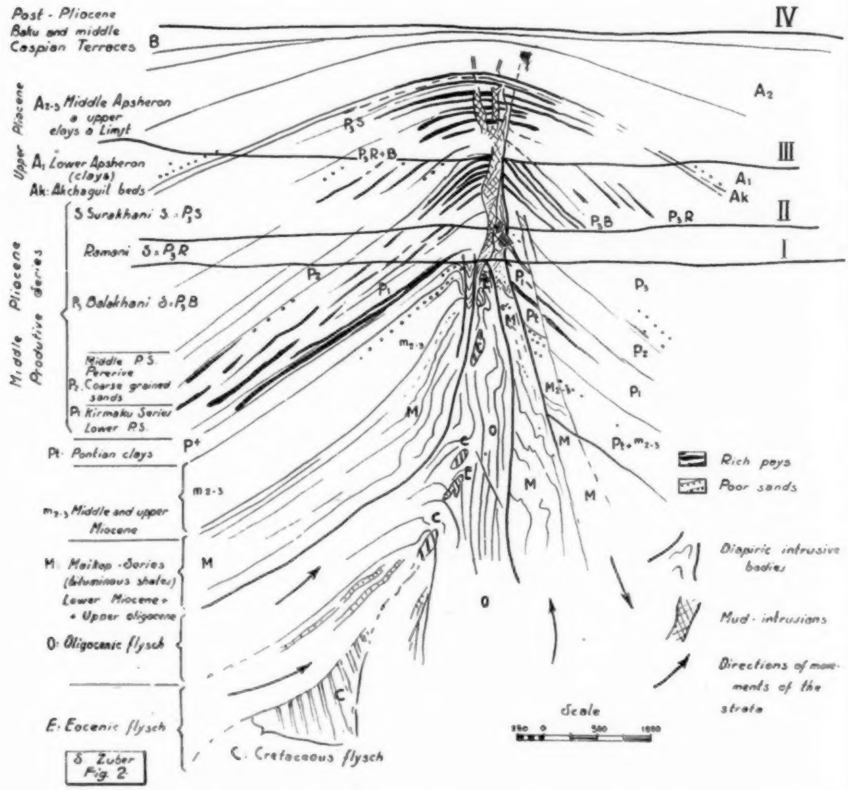

FIG. 2.—Ideal section across oil-bearing folds of Baku type. In the section are superposed simplified sections of several anticlines, the morphology of which is marked by thick lines. *I*. Binagadi: eastern sector (south-north). *II*. Binagadi: central part with Beiuk-Dagh mud volcano (south-north). *III*. Balakhani: central culmination with Bog-Boga mud volcano (north-south). *IV*. Surakhani (west-east): mud intrusive necks are taken from adjacent sector of same fold, that is, from Zikh field.

The deep levels of the folds are interpreted according to data taken along eroded anticlines of region.

The paroxysmic folding caused another phenomenon whose development makes both the east and the west ends of the Main Caucasus Range an area of special theoretical interest. It is the presence of huge mud volcanoes which characterize the tectonically weak segments of every anticline of Baku type and reveal the existence of deep structural disturbances.

It is evident, without further explanation, that the violence of the orogeny and the particular intensity of local dislocations have been due to the surface folding. Besides this circumstance, the main features of the diapiric anticlines of the Baku region give many hints of an existence of deep tectonic movements due to a sliding of the soft Neogene on its harder Paleogene underground. The anticlinal crests are too steep and the origin of the rocks of the intrusive bodies is too deep not to explain such an enormous upheaval as due to the peculiar and, in some places, tangential movements. In consequence of these, the older Paleogene (or Cretaceous) blocks, which appear like uprooted "klippen," ought to correspond with an effect of internal cutting off of the buried protuberances of the Paleogene. Its fragments picked from the Neogene masses might appear at the surface, being intensely laminated and completely isolated among the normally folded Neogene deposits.

On the other hand, it is quite reasonable that the Paleogene underground of the Neogene sheet is also folded, but its dislocations should follow the main structure lines of the Caucasus Range rather than the local plicative disturbances near the surface.

One of the structural features just mentioned should be explained. This feature is the activity of the mud volcanoes within the anticlines of the Apsheron Peninsula. Their existence enables us to define their position in the folds in the following manner. The presence of intrusive bodies of highly dislocated strata connected with a vertical movement of laminated blocks causes muddy, gaseous masses composed of the débris of the crumbled beds. Their fluidity depends on the consistency of the destroyed rocks and their quantity is in a direct relationship with the violence of the tectonic surface movements. The "roots" of the mud necks or diatremes are collocated on the top of the intrusive bodies or on their contacts with the untouched beds. The activity of the mud volcanoes, sometimes quite surprising in their intensity, depends on the mud reserves which can be driven outward until they reach the surface. In such cases they form eruption cones of considerable dimensions.[8]

[8] The literature on the diapiric tectonics in the Caucasian countries is abundant. The writer cites only the works which are accessible to the European reader. The thesis

The oil content of the Baku anticlines is not less characteristic than their tectonics. Only Middle Pliocene beds (Baku Productive series) are industrially petroliferous. Numerous "pays" are distributed from the top of this complex to its base, which is deposited on the impervious Lower Pliocene (Pontian clays). The distribution of saturated sands is not completely regular. The upper, well developed arenaceous beds are saturated near the tops of the anticlines. The lower "pays," on the contrary, are somewhat lenticular, tending to reach the synclinal, peripheric sectors.

In several well protected fields, the sandy horizons of the Upper Pliocene (Akchaguil and Apsheron beds) are locally petroliferous.

Also, the stratigraphic complexes lower than the Pliocene which are entirely argillaceous are locally oil-bearing, but nearly deprived of any industrial importance. Isolated impregnations are common in the Upper and Middle Miocene beds and scarce in the shales of the Lower Miocene or of the Oligocene. In the western area of the Apsheron Peninsula, several small fields exist, now forgotten and abandoned, the oil of which belongs to the Miocene complexes.

There is great variability of the qualities of the oil vertically and horizontally. Similar conditions are revealed when analyzing the oil waters of the Baku anticlines. Although the main types of oil or of water follow the stratigraphy, they vary from field to field. This circumstance is valid not only for the main "pays" of the Productive series, but also for the lower strata.

As a rule, the crudes of the upper horizons of the Middle Pliocene are lighter and not asphaltic. The lower series are saturated with heavier asphaltic oils, but the Miocene oils belong mainly to the light kerosene types, although even among them heavy crudes can be found locally.

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on the paroxysmic processes of the Caspian surface folding has been dealt with in a classic manner by H. Abich, "Über eine im Caspischen Meere erschienene Insel," *Mem. Academie des Sciences* (St. Petersbourg, 1863). A general description of the genesis of the mud volcanoes with a bibliography is to be found in S. Zuber's, "L'activité des volcans de boue en connexion avec la structure des plis gazifères" and "Sur la structure des plis diapirs," *Travaux du I Congres Int. des Forages* (Bucarest, 1925), and in *Rev. Pétrolifère* (1926; Ed. spéciale). The diapiric structure of Neogene Caucasian folds has been recognized and described by I. M. Goubkin, "Geologische Forschungen im Erdölgebiete von Kuban," *Mém. Comité Géologique*, No. 115 (Petrograd, 1915), and in the "Geol. Erdölforschungen im NW. Teile der Halbinsel Apscheron," *ibid.* (1914, 1915, 1916). The foregoing are in Russian with German summaries.

Although M. Gignoux shows a tendency to limit the definition of diapiric folds to anticlines with intrusive salt bodies ("Téctonique des terrains salifères," *Livre Jub. Centenaire Soc. Géol. de France*, Paris, 1930), as A. Wade also admits (*Jour. Inst. Petrol. Tech.*, No. 92, 1931), it is not to be contested that analogous tectonic features can be found in the Caucasian conditions without any participation of salt plugs. It is evident that the tectonics of the Caucasian diapiric folds need no salt bodies and notwithstanding this, they remain distinctly diapiric.

The salinity of the oil waters shows a high saturation on the top of the Productive series and diminishes with depth. The Miocene waters show a weak salinity. Among their components the carbonates prevail, but the waters of the Productive series are rich in chlorides.

The distribution of the oil[7] is clearly anticlinal, although some tendency to widespread impregnations is observed in many complexes, especially, as previously recorded, in the lower series. On the top of several anticlines with the covering beds preserved, the productivity is weaker than in the more distant sectors. This is mainly due to the post-Pliocene disturbances connected with the presence of the mud volcanoes or of the common intrusive bodies and depends on the undue water circulation.

The oil-bearing anticlines of the Baku type occupy a wide region that reaches the low plain of Kura River. The really rich fields are known only in the immediate vicinity of Baku.

With the foregoing facts we can now proceed to summarize all the peculiarities for defining the principal criteria which characterize the Baku type.

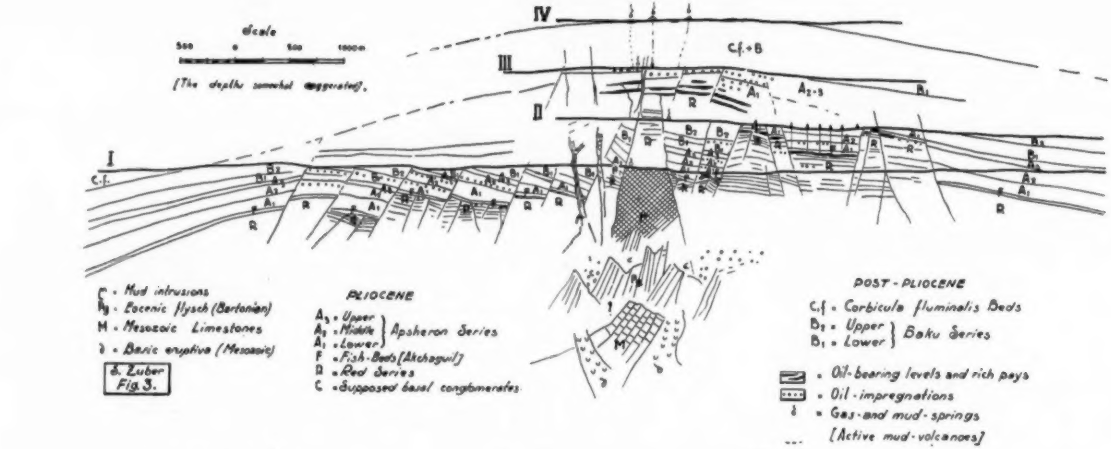
1. Distinctly folded diapiric, short anticlinal crests, with laminated intrusive bodies composed of pre-Pliocene strata. Traces of paroxysmic post-Pliocene final folding; variability of orogenic directions, tendency to form anticlinal arches and axial knots
2. Presence of intrusive necks and diatremes due to active or fossil mud volcanoes
3. Absence of great unconformities from Mesozoic era to Neogene except on tops of anticlines, due to slow wave-like orogeny through Pliocene
4. Argillaceous consistency of whole Neogene except of Productive series which are half arenaceous
5. Very frequent but local and poor oil impregnations in pre-Pliocene deposits. Highly saturated, numerous "pays" in Middle Pliocene. Anticlinal distribution of oil well expressed
6. Great variability of oil and water, vertical and horizontal

It is worth mentioning that the same tectonic type exists, as previously recorded, at the west end of the Caucasus Range on the Taman and Kerch peninsulas (Crimea) along the shores of the Sea of Azov. The structure and the low content of the pre-Pliocene strata show the same characteristics, including the presence of frequent mud volcanoes. The Pliocene, on the contrary, contains, with few exceptions, no oil; therefore, the Kerch-Taman folds should not be taken into consideration like their Caspian homologues.

[7] The subdivision of the horizons has been the result of long and exhaustive studies of the following geologists, published in Russian: M. Abramovich (Surakhani oil fields) S. Apresov (Ramani); D. Golubiatnikov (Bibi Eybat and Shubani); S. Kovalevsky (Bibi Eybat); N. Usheikin (Balakhani, Surakhani); S. Zuber (Balakhani, Binagadi).

D. V. Golubiatnikov, "Detailed Geological Map of the Apsheron Peninsula: Atashka Sheet," *Mém. Com. Géologique*, No. 130 (Leningrad, 1927). In Russian with numerous maps and profiles.

S. Zuber, "Die Erdöllagerungsverhältnisse in Binagadi bei Baku, genetisch betrachtet," *Petroleum*, Vol. 22, No. 8 (1925). Industrial stratigraphy of the oil-bearing horizons summarized.



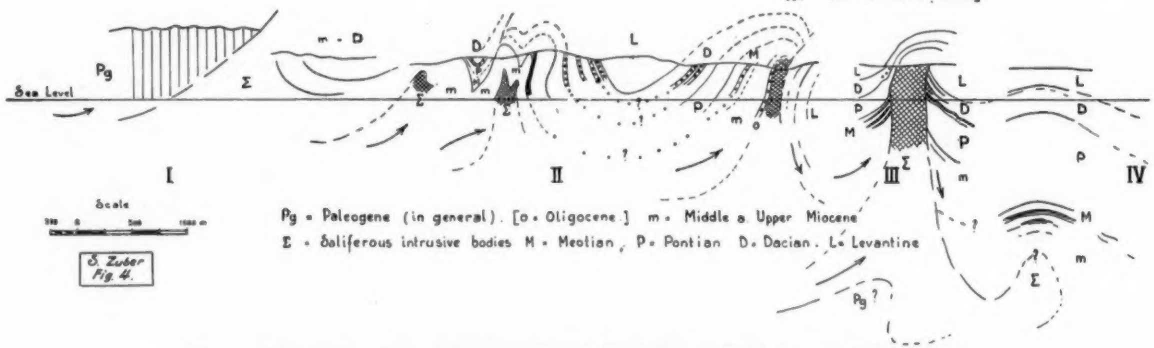


FIG. 3.—Ideal section across oil-bearing uplifts of Cheleken type. Thick lines mark the following generalized sections superposed one on another.

I. Central Cheleken: section across Aligul fossil mud volcano (southwest-northeast).
II. Cheleken: western sector (southwest-northeast). Wells mark productive area of Gadjinski's plot.
III. Nephte-Dagh (south-north).
IV. Southern area of trans-Caspian Coastal Plain.

FIG. 4.—Sections across Roumanian oil-bearing belt of Prohova. (After I. Atanasiu, Krejci, Mrazec, Preda, Pustowka, and the writer's own studies.) *Black:* oil "pays." *Dotted:* asphaltic oil impregnations. *Arrows:* main directions of tectonic movements. *I:* carried Carpathian margin. *II:* Matitza section. *III*: Moreni-Tzuicani (analogous to main oil fields of Baicoi, Ochiuri, et cetera). *IV:* Boldeshti (tectonically analogous to Cepturo, Ariceshti, et cetera).

II. CHELEKEN TYPE

The Pliocene series, which occupy nearly the whole surface of the post-Pliocene uplifts of the trans-Caspian Coastal Plain belong to an analogous group of Pliocene and Lower Quaternary sediments similar to those of the Apsheron Peninsula.

Their tectonics depend on the general downthrow of the whole Neogene area caused by large faults which limit the coastal plain on its east side. As a result, the general structure is quite different from the folds developed on both ends of the Caucasus Range. At the base of the Neogene series and, in places, of the Paleogene, as shown from the studies on the margins of the coastal basin, great unconformities exist. The soft-bedded deposits lie on the Mesozoic rigid limestones, pierced by numerous dikes of igneous rocks. The aforementioned post-Pliocene uplifts are anticlinal, but no regular folding is to be observed. The continuous upheaval of the Pliocene beds has been accompanied by an intense block-faulting followed by local, sometimes very sharp discordances of all the complexes as late as the Quaternary deposits.

Also the presence of numerous mud volcanoes, active since the Upper Pliocene, is to be noticed. Their genesis can be explained through the violence of disjunctive movements, and, as also in the Caucasian case, through the cutting off of the protuberances of the Paleogene strata which are predominant among the erupted materials. The presence of fragments of Mesozoic rocks, very common among the erupted products, is connected with the development of conglomerates on the base of the continental Pliocene deposits.

The oil content is merely connected with the top of the half-desert and half-lagoonal, so-called Red series recognized as a homologue of the Productive series of Baku. Also the Upper Pliocene shows several oil-bearing horizons, extremely interesting from the point of view of their genesis, but of little industrial importance.

As the oil accumulations are near the uplifted sectors, the oil is generally anticlinal, although the production of the good sectors of the Island of Cheleken showed the best "pays" in the downthrown well protected blocks.

The uniformity of the quality of the oil is worth mentioning. It is rich in paraffine wax (4–5 per cent) and lubricating fractions.

The general richness in paraffine wax has caused the formation of numerous and rich ozokerite veins, developed along the crevices in communication with the lower faulted oil-bearing strata.

The salinity of the waters is very high in all the horizons (20°–22° Bé.). They are of the chloride type only and uniform like the oils.

Their high temperature of 40°–72°C. (Cheleken) is a puzzling problem, not yet sufficiently explained, due perhaps to the presence of recent intrusions of igneous rocks below the Pliocene strata, but completely unknown along all the coastal area.

The oil deposits of the Island of Cheleken constitute a type by themselves quite original and nearly without analogous examples. The classic works of Kalitzki[8] have thrown much light on their genesis, as on the structure of all the Pliocene formations of the whole trans-Caspian Coastal Plain with all their exceptional richness in strange geologic phenomena.

As the base type, only the Cheleken type is to be considered. The other uplifts of the same region are to be classed in the same category, although their industrial oil content is somewhat problematic except the oil field of Nephte-dagh that has recently become very promising.

The following characteristics summarize the Cheleken type.

1. Wide, flat, frequently and intensely block-faulted post-Pliocene uplifts. Traces of continuous upheaval of the whole mass and contemporaneous, down-faulted blocks
2. Presence of mud volcanoes, fossil or active in each uplift
3. Local but very frequent unconformities throughout the Pliocene and Quaternary. Huge unconformities on the base of the Neogene
4. Argillaceous consistency of the Upper Pliocene and Molasse and very sandy nature of the Middle Pliocene
5. Oil-bearing on the top of the "Red series" (Middle Pliocene) and several well saturated but very thin horizons in the Upper Pliocene. Circulation along the faults and crevices. Traces of natural oil-sand eruptions from the strata, whose impervious cover has been eroded until insufficient to support the internal pressure of the gas. Industrial production from the buried downthrown blocks (Cheleken)
6. Oil rich in paraffine wax, uniform. Waters extremely abundant, in the whole Red series, of high salinity (chloride type). Exceptionally high temperature (40°–72°C.) in the Red series (Cheleken)

III. PRAHOVA TYPE

The literature on the Roumanian oil fields[9] is so well known that there is no need to enter into details, as in the former cases. A few remarks will be sufficient for clearing up the differences which exist between the Baku type and the main Roumanian, that is, the Prahova type.

[8] "Über die Lagerung des Erdöls auf der Insel Cheleken," *Mem. Com. Geol.*, No. 59 (St. Petersbourg, 1910). (Russian and German.) "Cheleken" (with M. Weber) *ibid.*, No. 63 (1911). "Nephte-dagh," *ibid.*, No. 95 (1915). Several papers of Kalicki on the trans-Caspian coastal uplifts appeared in the Bulletins of the Geological Committee of Petrograd (1914–1916); Boia-Dagh; Kum-Dagh, Chikishliar).

[9] The principal publications are:

Krejci, *Die rumänischen Erdöllagerstätten* (Stuttgart, 1929).

Macovei, *Rumänien. Die Erdöl-, Gas-, und Asphaltlagerstätten. Das Erdöl* (Engler-Höfer), Leipzig, 1930.

Mrazec, "Apercu sur le caractere des gisements de petrole de la Roumanie," *Pub. Faculté des Sci. Univ. Charles*, No. 118 (Prague, 1931). References to the literature are included in the foregoing books.

The linear disposition of the sub-Carpathian folds parallel with the principal tectonic lines of the Carpathian Range, is especially noteworthy. The final folding occurred at the beginning of the Quaternary, but was preceded by gentle and continuous push, the origin of which is to be sought in the block-thrusting of the Carpathian nappes. No paroxysmic movements are noticeable like those along the extremities of the Caucasus Range.

The distinct and classic diapiric structure is due to the presence of intrusive salt bodies. The piercing salt bodies belong, according to the opinion of a majority of Roumanian geologists (except Popescu-Voitesti), to the Lower Miocene. Their structûre reveals the hidden thrust movements of their underground (Teisseyre), with which the zonal disposition of the folds corresponds. Each zone has its own profile highly dislocated on the margins, near the thrust blocks and smoothly folded on the peripheries of the sub-Carpathian region.

The mud volcanoes are absent in the richly saturated belts. They appear only on the north, but are isolated and do not possess such interesting features as the Caspian phenomena.

The following characterstics belong to the Prahova type.

1. Zonally disposed diapiric anticlinal crests with intrusive salt bodies within. Gradual folding from Middle Pliocene to Lower Quaternary. A tendency to form huge faults and flexures on the peripheric side of the anticlines. Margins of the whole region intensely folded, the peripheries smoothly folded

2. Variability of forms of the salt bodies that, at a certain rate, take the place of the mud plugs of the Caspian anticlines

3. Local and insignficant unconformities on the summits of the anticlines

4. Molasse-like consistency of all the series that are building the sub-Carpathian uplifts. Thoroughly argillaceous—the Pontian beds. Occurrence of lignites among the "pays" of the Dacian series

5. Poor and insignificant oil in the Lower Miocene. Rich and numerous "pays" in the Upper Miocene (Meotian) and in the Middle Pliocene (Dacian). Anticlinal distribution of the oil, except in some cases near the margins with synclinal asphaltic impregnations

6. Uniformity of oils and waters, vertical and horizontal

IV. MEDITERRANEAN TYPE

As has been stated in the first pages of the present paper, the Mediterranean deposits show much originality due to their genesis in isolated basins. They are connected with the Middle and Upper Miocene sedimentation in the lagoons and basins along the formerly uplifted, eroded, and fractured older massifs, the development of which depended directly on the existence of larger or narrower ditches without any regard to the tectonics of their subsurface. In the majority of cases such uplifts strictly correspond with the anticlinal areas, but the origin of the deep sectors can be due to the graben-like down-fault-

ing of blocks or to erosion with formation of valleys filled afterward by Neogene sediments.

In consequence of this, such Neogene transgressive basins do not form regular synclines with their margins raised and are commonly limited through a system of faults and fractures without any regular impervious cover. The purpose of the impervious cover is fulfilled by the protecting faults whose isolating influence is commonly noticed. The size of dislocations affecting the Neogene masses is not great, as a rule, especially in comparison with the structural disturbances of the older subsurface. Also a certain independence of movements of the soft masses of the Neogene is worth mentioning.

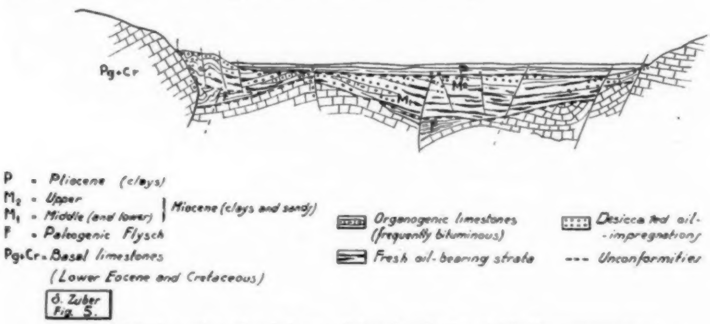


FIG. 5.—Ideal section through an oil-bearing basin of Mediterranean type.

The unconformities are generally very intense, not only between the subsurface and the main mass of the Neogene, but also among the Neogene strata themselves. In many places the thickness of the Neogene series, rather scarce in some sectors of the basins, rapidly increases where joining the peripheric, perfectly synclinal areas away from the influence of the older massifs.

When oil-bearing, the strata of this kind of deposits are, as a rule, irregularly impregnated. They do not follow the upraised sectors or secondary folds, that in some places exist within the basins. The "buried hills," even where "reflected," are to be avoided, because they are ordinarily exhausted by erosion before or during the formation of upper horizons that serve as somewhat protecting cover without any real importance.

As the oil occurrence is generally synclinal, the productive sectors are to be sought down-dip, that is, from the peripheries toward the center where the well protected blocks can be detected. It is worth mentioning that the paleogeographic conditions of the areas where

such oil deposits occur generally indicate that no anticlinal oil-bearing structures formerly existed.

The occurrence of bituminous coal in the Neogene areas of this kind is highly instructive.[10] Where it disappears the same horizons which have shown themselves as lignitiferous become, instead, oil-bearing and *vice versa*. The transition commonly occurs gradually with many stages between the bituminous lignite and asphaltite-like coals that near the oil deposits smell of oil.

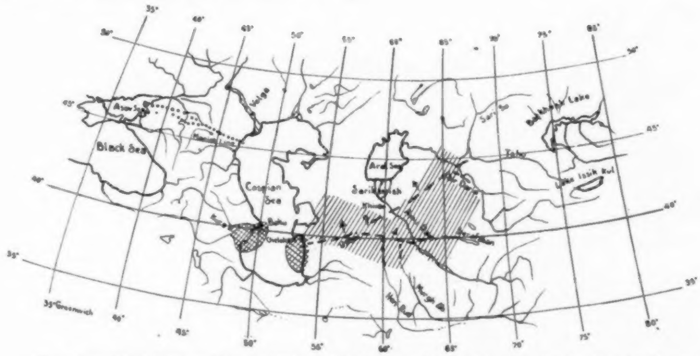


FIG. 6.—Sketch map of post-Pliocene hydrography of Caspian basin. *Dashed lines:* Paleo-Amu Daria River system. *Arrows:* directions of displacement of Amu River bed. *Squared:* deltas of Amu and Kura. *Shadowed:* Uplifted trans-Caspian area (marked schematically). *Dotted:* ways of penetration of *Cardium edule* into Caspian Sea (Manich line).

The oils of this kind of deposits are very heavy (0.92–0.99) asphaltic, easily oxidized, and with much sulphur (3–5 per cent). Near the outcrops and especially in the crevices, the coagulated oil forms asphaltic veins and nests.

The waters are sulphurous and of weak salinity. The scarcity of salts (chlorides) is due to a circulation of rain-water, which is facilitated by the structure, which does not protect the deposits sufficiently.

Although the deposits of Mediterranean type are characteristic through an abundance suggestive of the outcrops of oil- or asphalt-bearing strata, it can not be said that their industrial value is always worth the researches. On the contrary, their real oil content is rather scarce. They should be treated as a particular type in consequence of their genesis, tectonics, and common occurrence, rather than because of their industrial importance.

[10] S. Zuber, "Die Bildung des Erdöls und seiner Lagerstätten im Lichte migrations-verneinender Tatsachen," *Int. Zeits. für Bohrtechnik und Geologie*. (Verlag H. Urban, Wien, 1932.)

When examining the ideal sections, the reader will be able to distinguish many common features between the Mediterranean type and the narrow oil-bearing basins of Czechoslovakia. Their origin and the geologic age is analogous and it is not surprising that they are similar. Also the oil-bearing graben of Pechelbronn and the asphalt occurrences of the other regions of France[11] reveal a close relationship with these features. The latter are Oligocene in age, but their genesis is the same, that is, they depend on an accumulation of sediments on the eroded older rocks, with great unconformities at the base of the transgressive strata.

The main characteristics of the Mediterranean type are as follows.

1. Irregular Neogene basins situated on eroded subsurface, composed of older rocks. Disjunctive dislocations prevail. The margins in some places upraised and steep-dipping or cut off by fractures, commonly of huge dimensions. Folds rather scarce and depending on post-Miocene marginal wrinkling
2. Presence of fractures filled with fragments of broken beds
3. Great unconformities at base and within Neogene deposits. Great contrasts in thickness of various Neogene strata. Lack of covering beds common
4. Molasse-like consistency of Neogene deposits. *Lithothamnium* and other organic limestones widespread in Middle and gypsum in Upper Miocene. No salt. (The lithology of the Neogene graben-like basins, developed on the eroded subsurface, is very characteristic and well known. Therefore no mention of their occurrence has been made previously.)
5. Oil impregnations in the Upper and granular organic bituminous limestones in the Middle Miocene, in some places of favorable aspect, but only exceptionally of industrial value, which is merely due to insufficient preservation of deposits. Oil distribution prevailingly synclinal
6. Heavy asphaltic oils and sulphurous waters of low salinity, analogous in all deposits. Common presence of lignites in the horizons of Upper Miocene, the same that are oil-bearing elsewhere, and hence non-lignitiferous

[11] See the articles of M. Gignoux and of W. Wagner on the French oil deposits in *Das Erdöl* (Engler-Höfer), Leipzig, 1931.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 6 (JUNE, 1934), PP. 777-785, 1 FIG.

PALEOGEOGRAPHY OF OIL-BEARING DEPOSITS IN PONTO-CASPIAN COUNTRIES[1]

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ABSTRACT

In studying the peculiarities of the sedimentary content of the several petroliferous basins in the Ponto-Caspian countries, the writer briefly outlines the geological formations from Upper Pliocene downward through Lower Miocene and shows on a map the general location of six ancient uplifts or masses which were the sources of the more or less isolated oil-bearing centers. The ancient masses are: the Pannonian mass, the Vallaco-Pontian mass, the Crimean folds, the Suram mass, the Kura mass, and the Manguishlak folds. The three rich oil zones are the Middle Pliocene (Caspian oil fields), the Middle Pliocene and Upper Miocene (Prahova fields), and the Middle Miocene (Grosny fields).

INTRODUCTION

Late Neogene time in all of eastern Europe was characterized by great orogenic activity. Around the older folded uplifts gradually rise the recent uplifts. The large marine belts which form the remnants of the ancient Tethys become narrower and show a tendency to become transformed into isolated basins. Well defined peculiarities, first of the sediments and afterward of the faunas of each basin of the more or less isolated straits and lagoons can be noticed almost as early as the Middle Miocene. Instead of the widespread uniform facies, everywhere there are localized types of deposits, whose variability increases throughout the Pliocene.

The isolation of the marine basins caused increasing continental climatic conditions. The desiccation of central Asia which began during the Upper Paleogene greatly affected all the Ponto-Caspian basins since the end of the Miocene, but its predominant influence was in the Middle Pliocene. It explains the commonly arid or semi-arid character of the Pliocene formations.

The folding movements continued almost to the present; therefore, all the Pliocene and early Quaternary strata are more or less

[1] Read by title before the Section on the Geology of Petroleum, of the 16th International Geological Congress, at Washington, D. C., July, 1933. Manuscript received, December 2, 1933.

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folded, and the recent terraces are uplifted or faulted. As perfect or nearly perfect isolation of the basins of the Ponto-Caspian countries allows detailed investigation of sedimentary conditions across the whole region of each basin, it is easy to observe how the fluviatile or torrential deposits of semi-desert character gradually change into lagoonal and brackish deposits. Their thickness depends mainly on the temporary conditions of the transporting medium: on the activity of the fluviatile drift that is able to form widespread sheets of deposits, or on the activity of the desert torrent that accumulates huge masses only near the margins of the mountains.

Every sedimentary region has for certain epochs several types whose peculiarities can be classified according to their local conditions. When analyzing them, we can observe how the gradual changes of the lithologic character of the deposits are related to the oil-bearing conditions. We are able to distinguish for each epoch and for each basin its own petroliferous belts related to the overlapping of separate delta systems. Some basins of this kind are very richly petroliferous; others, though lithologically promising, do not contain any definite, exploitable bed. Therefore, a question arises, "What conditions govern the distribution of the oil occurrences?"

Every reconstruction of the Ponto-Caspian Neogene basins must take into consideration the position of the older uplifts whose existence has influenced first the sedimentation along the marginal belts and afterward the folding of the recently formed very thick and Molasse-like deposits. Also, the main directions of the folding and faulting should be analyzed in relation to the differences which exist between the Miocene and the Pliocene shore lines.

Petroleum geologists seem to have given little attention in the past to the location of the old pre-Alpine massifs still existing and eroded during the formation of the Miocene deposits, whose débris has given the materials for building up the thousands of meters of the Neogene strata. These massifs began to disappear contemporaneously with the tide-like folding and thrusting movements of the recent deposits.

STRATIGRAPHY[3]

The following description gives the stratigraphic systems from east to west. The subdivisions are simplified. (C: Caspian and eastern Caucasian region. Cr: Crimea and western Caucasus. R: Roumania.)

[3] Most of our knowledge on the stratigraphy of the whole Ponto-Caspian area we owe to the late N. Andrusov, whose starting point was the Caucasian Neogene. In his classic monographs he made a very careful subdivision of all the stages of this era and a paleogeographic reconstruction of the basins. The problem of migration and distribution of the Pliocene faunas was set forth in the works of V. Bogachev and A. Pavlov.

POST-QUATERNARY AND QUATERNARY

C: Several stages of Caspian terraces; at base, Baku series (brackish)
Cr: Marine terraces
R: Fluviatile terraces; at base, continental strata of Candeshti

UPPER PLIOCENE

C: Apsheron series (brackish)
Cr: Tshauda series (brackish)
Kuialnik series (brackish)
R: Levantine stage (fresh water)

The brackish faunas are prevailingly similar to those of the present Caspian fauna. Lithologically the deposits show an abundance of fluviatile beds, with interbedded shell-limestones and argillaceous delta or lacustrine sediments.

MIDDLE PLIOCENE

C: 2. Akchaguil series (brackish, with pseudo-Sarmatian fauna)
1. Productive series of Baku, Red series of Cheleken, conglomerates at base of Akchaguil

Prevailingly desert deposits, development of continental lacustrine sediments influenced by the fluviatile (delta) deposits. Locally fresh-water fauna (Baku).

Cr: Kimmerian stage (brackish with rich fauna of degenerated, some gigantic *Cardidae*)
R: Dacian stage (faunally analogous to Crimean zone)

During the Middle Pliocene the Caspian region passes through a stage of notable desiccation with a disappearing of brackish sediments. Intense fluviatile and lacustrine sedimentation, everywhere under arid climatic conditions, is predominant. The intensity of sedimentation increases with rapid orogenic movements. At the end of the epoch a huge basin of the Akchaguil stage is formed, the shores of which still keep their desert character.—S. Zuber.

While in the east continental conditions of sedimentation prevail, the Euxine countries show a development of two or three relatively independent basin systems with a noticeable variability of the shore lines.

LOWER PLIOCENE

C.—Cr.—R: Pontian stage (several prevailingly argillaceous series with brackish fauna)

The Pontian stage with many separate brackish basins indicates an epoch of relative tranquillity.

UPPER MIOCENE

C.—Cr.—R: Meotian stage (brackish, Sarmatian fauna)

Prevailingly argillaceous and sandy deposits are locally developed in the Caspian region. Their importance increases toward the west (Crimea-Roumania) where they form a definite series.

C.—Cr.—R: Sarmatian stage
3. Khersonian series (with *Mactra caspia*)
2. Bessarabian series (with rich normal Sarmatian fauna)
1. Volhynian series (prevailingly with *Ervilia*)

The three series are differentiated in all the Ponto-Caspian countries excepting the Baku region, where no stratigraphic unit is easily recognized mainly because of a lack of fossils. According to Golubiatnikov, the Diatomaceous clays form their Flysch-like eastern Caucasian equivalent. The Upper Sarmatian is nearly absent in sub-Carpathian Roumania, but is well developed in southern Russia (Crimea, northern Caucasus).

Much has been done by the Russian oil geologists: D. Golubiatnikov, I. Goubkin, K. Kalitzki, Vassoievich, and others.

Among the geologists who have worked in Roumania great praise is due to J. and S. Atanasiu, Jonescu-Argetoaia, Macovei, Mrazec, Sevastos, and Teisseyre. A complete subdivision of the Roumanian Tertiary with comprehensive references is to be found in the work of K. Krejci, *Die rumänischen Erdöllagerstätten* (Stuttgart, 1929).

MIDDLE MIOCENE (VINDOBONIAN)

C.—Cr.: 3. Konka (Buglov) series (half brackish)
2. Karagan series (*Spaniodontella:* highly saline fauna)
1. Chokrak series (marine fauna)

Two fundamental facies are recognized. Along the mountain ranges appear the Flysch argillaceous complexes of considerable thickness analogous in facies to those of the marginal Sarmatian, Meotian, and Pontian stages (synclinal facies).—S. Zuber. Along the northern limits of the Neogene deposits are developed highly fossiliferous sandy or calcareous deposits of littoral type (anticlinal facies).

Along the Roumanian Carpathians the Middle Miocene forms the upper beds of the Saliferous formation.

LOWER MIOCENE

C.—Cr: Maikop series. Bituminous brownish shales, typical of the margins of the Great Caucasus. The lower horizons probably correspond with the top of the Oligocene strata.

R: 2. Burdigalian
1. Aquitanian (Cornu series)

Conglomerates, clays (some bituminous like the Maikop strata), sandstones. Both stages form the main part of the well known Roumanian Saliferous formation.

PALEOGEOGRAPHY

There are three main factors which govern the distribution of the sediments in every sector of the described regions. First, we observe the continuous changing of the shore lines of the basins; next, their relationship with the outlines of the ancient uplifts. Their interference, largely dependent on the direction of the great crustal movements, when well understood, gives a complete picture of the Ponto-Caspian Neogene paleogeography. The third factor, merely interesting as far as it concerns the petroliferous processes, is the supply of sediments through each stage. Each of those factors is so closely connected with the others that it becomes sometimes very difficult to analyze them separately. Therefore it is necessary to assume a kind of artificial subdivision for the purpose of this paper.

The paleogeographic reconstruction of the shore lines of the whole area shows a fact that should be particularly emphasized. It is well known that the seas which cover the wide areas of the region maintain, until the Upper Miocene, their west-east alignment. At the end of the Miocene a very fundamental change takes place, because from this moment the basins show a tendency to cover the belts perpendicular or oblique to the older direction. This is the reason why the Ponto-Caspian area becomes, during the later Neogene and until the present time, an area of a continuous struggle between those two tectonic directions, and why all sectors of the shore lines and the folds of each stage have two tectonic components. Until the Upper Miocene the longitudinal directions prevail, but during the Pliocene, they give place to the perpendicular directions that predominate until the Quaternary, when the Euxine faults accentuate anew the existence of the longitudinal forces.

Now the question arises how the pre-Pliocene uplifts, along which the sedimentary accumulation took place, were disposed. It is of secondary importance to determine to which system of folding such uplifts belonged. It seems sufficient here only to mention that they were partly Hercynian and partly early Alpine upheavals. The late main Alpine folding took place in the Ponto-Caspian countries very recently and certainly was only commencing while the Pliocene sediments were being formed.

The sedimentary rôle of the old uplifts has repeatedly attracted the attention of many geologists. The influence of the Dobrodgean Mountains on the Carpathian Tertiary sedimentation was stated many years ago by R. Zuber. Later, the ideas of that author were elaborated by Murgoci and then appeared in modern form in the synthetic interpretation of R. Staub and Seidlitz.[4] The main features of the Caucasian tectonics have been established by Oswald, Bogachev, and finally by J. Nowak.

The limitations of this article preclude discussion of the age of each system of folding to which belong the peculiar pre-Miocene upheavals. The writer thinks it is sufficient to point out only the main elements whose existence is evident in the stages when the petroliferous sedimentation was taking place. From west to east these elements are the following.

The Pannonian mass (*A*, Fig. 1) continued to subside during the Miocene. Its remnants exist in the Bihor mass in Transylvania. The existence of the Vallaco-Pontian mass (*B*) is evidenced not only by the Dobrodgea Hills, but also by the general character of the shores of the Black Sea, suggesting the very wide extension of this unit occupying at least nearly half of the present area of the Euxine Basin. Although the Crimea folds (*C*) belong to the Alpine system, their proximity to the Vallaco-Pontian mass merely buried on the bottom of the Black Sea renders possible a slight connection between the early movement of the so-called Crimean folds and the influence of the first system. The Suram massif (*D*) is an old folded block in central Georgia forming part of the southern Caspian mass of Staub, being its western segment. The eastern segment is found in the Kura mass (*E*), remnants of which the writer discovered when examining the boulders ejected by the mud volcanoes along the Caspian shores. It is assumed that the boulders came from below the bottom of the Caspian Sea. The sinking and the final disappearance of this sector is very recent, because it certainly existed during the Middle Pliocene.

[4] Seidlitz, *Diskordanz und Orogenese der Gebirge am Mittelmeer* (Berlin, 1931).

The last unit is to be sought in the now hidden extremities of the folds of Manguishlak (*F*).

The paleogeographic reconstructions of the whole Ponto-Caspian Neogene, that we owe mainly to Andrusov, follow only the traces of the Miocene and Pliocene deposits along the present shores of both seas. Therefore these reconstructions mark only the extreme extension of different stages, and can not take into consideration the existence of islands within each basin. It is too soon to try this kind of revision of the reconstructions of Andrusov, and for the present it must remain rather hypothetical. Notwithstanding this, a very important consequence follows as to the existence of the narrow straits between the separate basins instead of the widespread bodies of water. The writer has tried to express graphically all these conditions on the map shown as Figure 1.

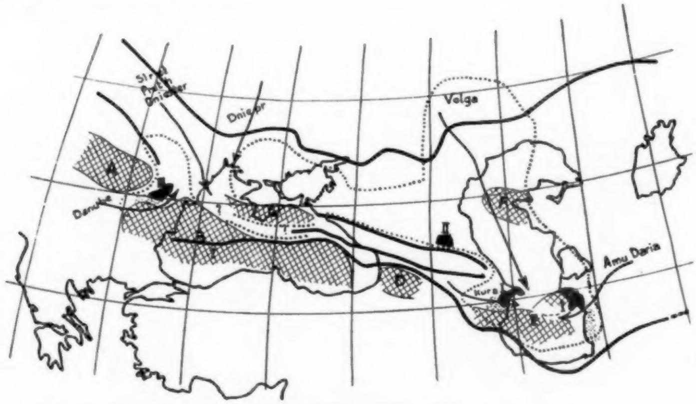

FIG. 1.—Paleogeographic map of Ponto-Caspian Neogene.
Heavy lines: main features of Miocene coast lines.
Dotted lines: main directions of Pliocene basins.
Arrows: Pliocene river systems and directions of their flowing.
Squared: pre-Pliocene massifs: *A*, Pannonian mass; *B*, Vallaco-Pontian mass; *C*, Crimea folds; *D*, Suram massif; *E*, Kura mass; *F*, folds of Manguishlak.
Black: petroliferous areas: *I*, Baku area; *II*, Grozny area; *III*, Prahova region.
Fine dots: hypothetical, richly petroliferous areas.

At any rate, the Pliocene sinking of older masses corresponds with highly important faulting along the Ural, that is, north and south, and shows a clear tendency to break the uniformity of the Alpine folds. As stated in the paragraphs on Stratigraphy, all the Pliocene stages show well expressed traces of fluviatile and delta sedimentation. Their characteristics continue through all the phases of the orogeny and

permit us to examine the dimensions and appreciate the longevity of every fluviatile or torrential system. The directions of water arteries correspond with the main structural features and this fact renders the analysis of the sediments very important, as the studies of V. Baturin[5] recently have shown.

Baturin, having examined the petrographic composition of the sands of the Middle Pliocene Productive series of Baku, took up the puzzling problem of the origin of the apparently continental deposits of this stage. His reconstruction proves the fluviatile origin of the series, whose sediments were connected with the wandering deltas of the antecedents of the rivers now forming deltas in the Caspian Sea.

The lack of sufficient data does not permit a similar reconstruction for the Roumanian sub-Carpathian Plains. Notwithstanding this, using the fragmentary paleogeographic evidence available, one can assume analogous sedimentary processes for the whole Roumanian and Crimean Pliocene.

In consequence of these interesting conditions, whose analogy can be sought in the results of the modern oceanographic studies of the recent Caspian and Euxine sedimentation, the Neogene strata appear as a formation due to a continuous overlapping of the deltas and of the sea-currents originated by them on the periphery of every deltaic area. Therefore it becomes quite evident how these deltaic areas, the position of which corresponds with the Talweg of rivers at right angles one to another, give rise to characteristics of the sedimentary conditions.

PONTO-CASPIAN PETROLIFEROUS AREAS

Although the whole Ponto-Caspian Neogene shows favorable conditions, we recognize only a few great oil-bearing centers. Oil occurrences of all degrees are as common as the outcrops of the Neogene, but the rich zones remain rather limited. Three of them are recognized:

Middle Miocene: Grozny oil fields (northern Caucasus)
Upper Miocene and Middle Pliocene: Prahova oil fields (Roumania)
Middle Pliocene: Caspian oil fields (Apsheron-Baku, eastern Caucasus, and trans-Caspian zone: Cheleken-Nephtedagh)

The most complete paleogeographic data available concern the Caspian oil-bearing belt. Having already published sufficient data on

[5] I. "Petrography of the Sands and Sandstones of the Productive Series."
II. "Physico-Geographical Conditions of the Productive Series," *Trans. Azerbaidjan Petroleum Inst.*, Bull. I (Baku, 1931). (Russian with English summary.)

the genesis of the Caspian deposits,[6] the writer merely mentions here the outlines of this problem.

Not every river, even when it carries abundant quantities of water into the sea, is able to furnish sufficient organic deposits to permit a formation of widespread regional saturation of the strata. It seems, as previously stated, that the best conditions are created by the encountering of several deltaic accumulations. This facilitates the favorable conditions, because not only do the terrigenous organic materials become deposited and not become dispersed, but also the algae and all the kinds of halogenic stenohaline plankton easily die and are buried along the meeting places of the fresh, brackish, and salt waters.

Analogous circumstances seem probable for the paleogeographic situation of the Roumanian fields. Merely the crossing of the longitudinal paleo- or pre-Danubian river system with the perpendicular of the Prut-Siretul-Dniester river-net would be a natural cause of the richness of central Roumania.

Sufficient data are not available to judge the petroliferous conditions of the Grozny Middle Miocene, but a similar sedimentation may be supposed according to a particular facies character of the strata along the corresponding sector of the northern Caucasus. Unfortunately this problem has not been sufficiently studied from this point of view; therefore, such an assertion is wholly hypothetical.

FUTURE RESEARCH IN PALEOGEOGRAPHICALLY FAVORABLE ZONES[7]

It is not asserted that our actual knowledge of the main oil-bearing belts of the regions described is thoroughly complete and that no new promising deposits can be discovered. On the contrary, we are acquiring every day new criteria which permit us to treat the problem of oil-finding regionally, as a result of the foregoing facts.

It is sufficient to limit the present remarks to two interesting zones. The first is the southern littoral belt of the Caspian Sea and the second includes the triangle between the Prahova fields now being exploited, the margins of the Dobrodgea Hills, and the Danubian Delta.

Both countries surely represent the zones where a gradual increase of thickness of the Neogene deposits takes place as far as they are developed along the dipping margins of old massifs surrounded by

[6] S. Zuber, *Die Bildung des Erdöls und seiner Lagerstätten im Lichts migrationsverneinender Tatsachen* (Wien, 1932).

———, *Internat. Zeits. für Erdölbergbau* (Verlag, H. Urban). References to the writer's former publications on this subject are to be found therein.

[7] S. Zuber, "Vers la recherche de nouveaux champs petrolifères," *Comptes Rend. Coupes Int. des Mines* (Liége, 1930).

lagoonal sedimentation regions. The writer has had occasion repeatedly to point out how the Flysch or Molasse sediments become petroliferous at a definite distance from the older buried massifs. This phenomenon is explained, as we know, through the enlarged theory of "buried hills" and therefore a noticeable quantity of the oil is to be expected, especially when we take into consideration that the opposite side of the basins is largely petroliferous.

On the other hand, it should be remembered that every margin of a torrential coarse-grained facies can have its lagoonal homolog which gradually becomes argillaceous and in such cases a zone of the transitional facies is, as a rule, petroliferous. The old massifs which appear as wide continental groups or archipelagoes, represent an element of the best conditions for the transportation of terrigenous materials. Torrential deposits in their vicinity very commonly become lagoonal and it is there that the oil deposits occur.

Now we understand why the promontories of the Dobrodgea Hills, now deeply buried under the Pliocene sediments of the Danubian Plain, should be tested. The oil-bearing beds were not only the Meotian and Dacian strata, as in the sub-Carpathian region. The Middle and the Lower Miocene also should be proved petroliferous, as in other countries of similar sedimentary conditions.

An analogous phenomenon is to be expected also near the remnants of the Kura mass or along the trans-Caspian Coastal Plain. These countries, as has already been recorded, were during the Pliocene a meeting-place of currents carrying organic material. These regions form the object of serious surveying by the Russian oil geologists.

EMBRYONIC OIL DEPOSITS

The classic studies of Arkhangelski[8] have thrown much light on the rôle of organic sedimentation at the bottom of the Black Sea. Analogous conditions are also recognized in the shallow northern areas of the Caspian Sea. The lithologic character of the deposits which are now being formed there is similar to that of the Upper Pliocene and several aforementioned Miocene series developed along the Carpathians and the Great Caucasus Range. The sedimentary conditions we observe in both seas justify us in supposing that a large quantity of organic material is being preserved and buried, undergoing petroliferous fermentation.

The configuration of the shore lines and the disposal of the main rivers corroborate this hypothesis because the present hydrographic features of the Ponto-Caspian countries show everywhere a direct descent from the Pliocene.

[8] *The Conditions of Oil Generation in the Northern Caucasus* (Moscow, 1927). Russian with an English summary.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 6 (JUNE, 1934), PP. 786-812, 7 FIGS.

PLIOCENE CONGLOMERATES OF LOS ANGELES BASIN AND THEIR PALEOGEOGRAPHIC SIGNIFICANCE[1]

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ABSTRACT

The Los Angeles Basin contains many thousand feet of Miocene, Pliocene, and Pleistocene strata, in which are numerous beds of conglomerate. In this paper the assemblages of rock types in the various conglomerates are considered, and an effort is made to correlate these assemblages with the materials in each of the source areas. Conclusions and inferences concerning the Tertiary history and paleogeography of the region are based on the composition of the conglomerates in the Tertiary sedimentary column, their relative positions in the column, their areal distribution, and their probable sources.

INTRODUCTION

Location of area examined.—The Los Angeles Basin, an area 50 miles long and 25 miles wide, is bounded on the north and northwest by the San Gabriel and Santa Monica Mountains, on the east and southeast by the Santa Ana Mountains and the San Joaquin Hills, on the south and southwest sides by the Pacific Ocean and the San Pedro Hills.

In this basin thick series of sedimentary strata were deposited during the Tertiary period. During the late Pleistocene and Recent epochs, alluvial fans originating at the mountain fronts advanced seaward and merged with marine deposits. They effectively conceal most of the Tertiary measures previously laid down. The present exposures of these rocks are confined, therefore, to the margins of the mountainous areas, and to the hills standing above the general level of the alluvial plains. Localities within the Los Angeles Basin which afford good outcrops of Pliocene strata are the San Pedro Hills, the hills in the northern part of the city of Los Angeles, Repetto Hills, Puente Hills, Burruel Point and the San Joaquin Hills. The geographic position of these is shown on Figure 1.

[1] Read before the Pacific Coast Section of the Association at the Los Angeles meeting, November 4, 1932. Manuscript received, December 8, 1933. Research problem, Department of Geology and Paleontology, California Institute of Technology.

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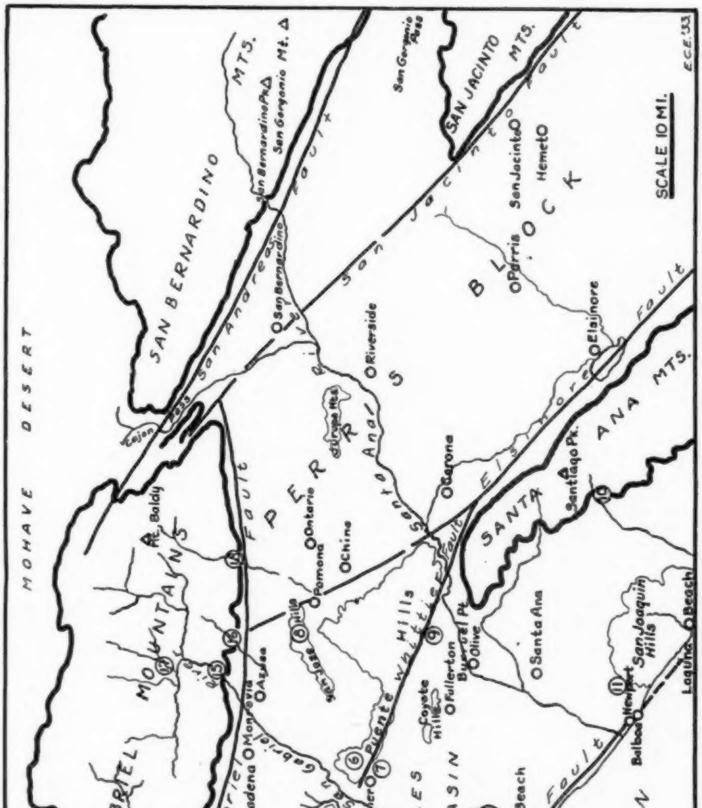

FIG. 1.—Index map of a portion of southern California. Numbers on map indicate localities mentioned in text. Faults after English, *U. S. Geol. Survey Bull. 768*, Pl. III.

The southern part of California may be subdivided into the following physiographic provinces: Ventura Basin, coinciding roughly with the area drained by Santa Clara River, Santa Monica Mountains, San Gabriel Mountains, Los Angeles Basin, Mohave Desert, San Bernardino Mountains, Imperial Valley, San Jacinto Mountains, Perris Block, and the Santa Ana Mountains, most of which are indicated on Figure 1. Of these the Ventura Basin, the Mohave Desert and the Imperial Valley did not furnish coarse clastic material to the Los Angeles Basin during Pliocene time and are not considered further. The Santa Monica, San Gabriel, San Bernardino, San Jacinto, and Santa Ana Mountains and the Perris Block remain as potential source areas. To these may be added whatever land may have existed farther southwest which is now under the ocean.

Methods.—The first operation taken in the investigation was concerned with the origin of the sediments. The potential source areas were examined and the formations in each district classified, so that if pebbles and boulders of those types were found in the conglomerates they could be assigned to their proper source. Rocks characteristic of certain areas and absent in others received special attention, as they would have much diagnostic value if encountered in the conglomerates.

The Pliocene strata were then studied. Pebbles and boulders in these strata were identified and pebble counts made. It was found that not only could individual pebbles with distinctive characteristics be recognized and referred to their respective source areas, but conglomerates could be treated in a like manner. The available conglomerates were diagnosed in this way, and from the data obtained the physiographic history of the region was formulated.

Acknowledgments.—During the preparation of this paper the writer was greatly aided and encouraged by J. P. Buwalda, chairman of the Department of Geology and Paleontology, California Institute of Technology; also thanks are due to Ian Campbell, Rene Engel, and John Maxson, of the same institution, for information furnished by them. The writer is also indebted for suggestions and criticisms to R. D. Reed, W. S. W. Kew, M. G. Edwards, G. H. Doane, D. C. Hughes, Boris Laiming, H. W. Hoots, H. L. Driver, W. H. Holman, Guy Miller, A. O. Woodford, W. J. Miller, F. E. Bell, and Hampton Smith.

PLIOCENE CONGLOMERATES OF LOS ANGELES BASIN

FORMATIONS PRESENT IN POTENTIAL SOURCE AREAS

SANTA MONICA MOUNTAINS.—(11, 14)[3] The Santa Monica Mountains consist of a low range about 45 miles long and 8 miles wide, extending

[3] Numbers in parentheses refer to Bibliography at end of paper.

east from Point Mugu on the coast to Los Angeles River north of Hollywood. Their greatest altitude is slightly more than 2,800 feet.

A varied assortment of rock formations is found in the Santa Monica Mountains. The igneous rocks consist of granite, granodiorite, diorite, basalt, trachyte, tuffs, and breccias. The sedimentary formations are as follows.

Triassic (?) Santa Monica slate.—A black slate and its more metamorphosed phases such as mica schist, dark gray phyllite, and a contact type containing idioblasts of cordierite.

Chico formation.—Brown and gray sandstone, conglomerate, and shale; reefs of white algal limestone.

Martinez formation.—Soft brown shale, sandy shale and sandstone, with hard limestone concretions containing fossils. Prominent discontinuous reefs of white algal limestone.

Vaqueros (?) and Sespe (?) formations.—Light gray and red conglomerates and conglomeratic sandstones.

Topanga formation.—Sandstone, conglomerate, and shale intercalated with basalt and pyroclastic rocks.

Modelo formation.—The lower part consists of soft, light gray-to-brown well-bedded shale, banded hard platy siliceous shale, thin and thick massive beds of sandstone, conglomeratic sandstone, and volcanic ash. The upper part is white "punky" diatomaceous and foraminiferal shale and fine sandstone. Hoots mentions that the Modelo formation contains numerous beds, concretions, and concretionary lenses of hard, light gray, yellow, and brown limestone. These are believed to be represented in substantial amounts in the Pliocene conglomerates exposed in the city of Los Angeles and elsewhere.

SAN GABRIEL MOUNTAINS.—(9, 12) The San Gabriel Mountains extend approximately east and west a distance of 60 miles and are 20 miles wide. The highest point, San Antonio Peak (Mount Baldy), has an altitude of 10,080 feet.

The rocks composing these mountains are almost entirely igneous and metamorphic. Common igneous types are granite, granodiorite, quartz diorite, diorite, dikes of pink quartz-orthoclase pegmatite and aplite, feldspathic porphyries, and diabase. Quartz-feldspar-biotite and quartz-feldspar-hornblende gneisses, primary and secondary, are abundant. Metamorphic types include quartzite, biotite schist, crystalline limestone and amphibolite. Arnold and Strong (1) list and describe the following rocks as representative of these mountains: biotite granite, quartz monzonite, granodiorite, hornblendite, aplite,

quartz-hornblende porphyry, diabase porphyry, hornblende diorite, diorite gneiss, biotite granite gneiss, and hornblende schist.

An extensive exposure of anorthosite of a distinct type occurs in the western portion of the mountains between Soledad Canyon on the north and the upper reaches of Tujunga Canyon and Mill Creek on the south. This rock is of a light, translucent, stone-gray color. It is composed of plagioclase feldspar and some irregularly distributed, bunchy, disseminated crystals of green hornblende. Individual crystals of the feldspar range from $\frac{1}{4}$ inch to 4 inches or more in width. The feldspar is andesine rather than labradorite, and there may be some question as to the propriety of the term "anorthosite." Hershey (8) calls attention to this occurrence in an early publication.

Pebbles and boulders of this anorthosite are found in the river gravels of Soledad Canyon, Pacoima Creek, Little Tujunga and Tujunga canyons, but are not found in the Arroyo Seco or other canyons farther east.

The western half of the San Gabriel Range (as well as Verdugo and San Rafael hills) contains a much greater proportion of rocks carrying flesh-colored orthoclase feldspar than the eastern half. Granite, aplites, and pegmatites of the quartz-orthoclase variety occur in abundance. They weather less rapidly than granodiorite and are well represented in float fragments scattered over the mountain slopes and in the river gravels.

An unusual rock which occurs extensively in the central part of the San Gabriel Range will be referred to in this study as "dappled" diorite. An excellent exposure of it in a recent road cut is located approximately two miles northeast of the confluence of the North and West Forks of San Gabriel River (Fig. 1, No. 17). Numerous pebbles and boulders of this rock are found in the stream channels from Pacoima Creek on the west to San Antonio Canyon on the east. The rock is medium grained, nearly white, but contains greenish black aggregates of biotite and hornblende. These aggregates are disc-shaped, about $\frac{1}{4}$ inch in diameter. Most but not all are in parallel arrangement, due, it is thought, to primary eutaxitic flow. Because of this the rock exhibits a gneissic structure. The feldspar is albiclase ($ab_{10-20}-an_{80-90}$) with $Ng > 1.530$, $Np < 1.545$. A small amount of quartz is present. This formation is found only in the San Gabriel Range and is diagnostic of it.

The eastern half of the San Gabriel Mountains contains white aplites and pegmatites, not found in the western half. They are composed of albite and quartz, with occasional orange-red garnets and flakes of colorless mica. A few pebbles and boulders of these types

were found in the river gravels of San Gabriel and San Antonio canyons. From a casual inspection one might mistake them for vein quartz or white quartzite, especially when they are badly chattermarked. They are unusually resistant to the agencies of weathering.

Representative groups of formations occupying various portions of the San Gabriel Range, as indicated by pebble counts made near the mouths of several large canyons, are here given (p. 792).

SAN BERNARDINO MOUNTAINS.—(16) The San Bernardino Mountains are almost due east of the San Gabriel Range and are separated from it by Cajon Canyon. They trend nearly east and west and are approximately 50 miles long and 20 miles wide. The two highest peaks, Mount San Gorgonio and San Bernardino Peak, have elevations of 11,485 and 10,630 feet, respectively.

By far the most abundant rock is pink granite, which locally grades into quartz-monzonite and gray granodiorite. Rocks of secondary importance are quartzite, schists, crystalline limestone, aplite, and pegmatite. The granites of the San Bernardino Mountains are composed mainly of quartz and flesh-colored orthoclase, with lesser amounts of biotite and other accessory minerals. The pink pegmatites and aplites are likewise made up of quartz and orthoclase, some of them exhibiting graphic intergrowth. Gray granodiorite is present in greater proportion in the eastern and western ends of the mountains than in the central part. Feldspathic porphyries and gneisses also occur locally.

SAN JACINTO MOUNTAINS.—The San Jacinto Mountains are approximately 50 miles east of the Los Angeles Basin. They are wedge-shaped, with the short side toward the southeast. They are separated on the north from the San Bernardino Range by San Gorgonio Pass, and are bounded on the southwest side by the San Jacinto Valley and drainage area. San Jacinto Peak has an altitude of 10,805 feet.

The San Jacinto Mountains are composed very largely of plutonic rocks, ranging from granite to quartz diorite, and their gneissic equivalents. Quartz diorite and granodiorite greatly preponderate over the more alkaline types. Frazer (6) classified 17 specimens as follows: granite, 3; quartz monzonite, 2; granodiorite, 3; quartz diorite, 9. The area also contains patches of metamorphic rocks which were surrounded and engulfed by the plutonics. They include such types as quartzite, crystalline limestone, various gneisses, mica, and hornblende schist and phyllite, similar in many respects to those in the San Bernardino Mountains.

PERRIS BLOCK.—(3, 4) The Perris Block is a long, irregularly rectangular, structural segment, with its long axis trending in a north-

Pacoima Creek (Fig. 1, No. 12)

	Per Cent
Granodiorite	17
Hornblende biotite gneiss	14
Diorite (hb)	12
Anorthosite	12
Pink pegmatite	9
Crystalline limestone	8
Granodiorite gneiss	6
Pink granite	5
Biotite schist	4
Pink aplite	4
Quartz diorite	2
Rhyolite porphyry	2
Dappled diorite	2
Quartzite	2
Hornblendite	1
	100

Arroyo Seco (Fig. 1, No. 14)

	Per Cent
Pink granite	16
Granodiorite	16
Pink pegmatite	13
Dappled diorite	12
Quartz diorite	9
Hornblende-biotite diorite	9
Biotite gneiss	7
Biotite schist	3
Pink aplite	6
Quartz monzonite	4
Quartzite	2
Hornblendite	2
Rhyolite	1
	100

San Antonio Canyon (Fig. 1, No. 18)

	Per Cent
Quartz diorite and gneiss	17
White quartzite	15
Granodiorite	11
Feldspathic porphyry	10
Biotite gneiss	6
Dappled diorite	6
Hornblende gneiss	5
White pegmatite	5
Dark quartzite (cf. Triassic)	4
Biotite schist	4
White aplite	4
Pink pegmatite	3
Sedimentary schist	2
Crystalline limestone	2
Pink granite	2
Vein quartz	2
Sericite schist	1
Basalt	1
	100

Tujunga Canyon (Fig. 1, No. 13)

	Per Cent
Pink granite	21
Granodiorite	16
Pink pegmatite	10
Anorthosite	10
Biotite schist and gneiss	8
Quartz diorite and gneiss	10
Pink aplite	6
Granodiorite gneiss	5
Crystalline limestone	4
Quartz monzonite	4
Hornblendite	3
Quartzite	2
Dappled diorite	1
	100

San Gabriel Canyon (Fig. 1, No. 15)

	Per Cent
Granodiorite and gneiss	18
Feldspathic porphyry	15
Dappled diorite	10
Biotite schist and gneiss	10
Hornblende schist and gneiss	6
Pink pegmatite	6
Pink granite	5
Pink aplite	5
Quartz diorite	5
White pegmatite	4
White aplite	3
Basalt	3
Crystalline limestone	2
Gabbro porphyry	2
Diabase	2
Quartzite	2
Chlorite schist	1
Pyroxenite	1
	100

west-southeast direction. It averages about 25 miles in width and is more than 60 miles long. It is bounded on the northeast by the San Jacinto fault zone and on the southwest by the Chino-Elsinore fault

system, above which rises the steep scarp of the Santa Ana Mountains. Toward the southeast the Perris Block rises gradually toward the Peninsular Ranges. The block is therefore a structurally and topographically depressed area. The maximum relief between the hills and lowlands within the block is not more than 1,000 feet.

Formations constituting the Perris Block are in many respects similar to those in the San Jacinto Mountains. The major portion of the area is underlain with quartz diorite and granodiorite. The hills and low mountains east of Temescal Wash between Corona and Elsinore contain large amounts of effusive rocks and various types of porphyry. These rocks vary in color from very light to dark gray. Occasionally they have a pinkish cast, as at the road cut one mile east of Corona on the road to Riverside. The porphyries contain quartz and plagioclase feldspar phenocrysts, up to ⅛ inch in diameter.

An area near Riverside is very interesting in its bearing on the present investigation. The Jurupa Mountains, 4 miles northwest of the city, are a group of hills about 6 miles long and 2 miles wide, projecting from 750 to 1,000 feet above the general low level of the Perris Block. Metamorphosed sediments, consisting of mica schist, various types of clastic rocks, and granular marble, compose the west end of the hills. Farther east the common types, quartz diorite, granodiorite, and quartz monzonite occur. The most important feature of the area, however, is the large number of dikes of white quartz-albite aplites and pegmatites. These dikes are well exposed in the Crestmore district near the east end of the Jurupa Mountains. Due to their superior resistance to erosion they form prominent ridges on the rounded surfaces of hills. The dikes vary in width from one inch to 20 feet or more, and may be traced for miles along a northwest-southeast trend. The hills are covered with rubble composed almost entirely of the dike rocks.

White pegmatite and aplite pebbles and boulders are found in abundance in some of the Pliocene and Lower Pleistocene conglomerates of the Los Angeles Basin. No outcrops of these rocks other than the ones here described were found in quantity in the entire area investigated, and the Jurupa Mountains and surrounding area are therefore considered to be the principal source of such material.

SANTA ANA MOUNTAINS.—(2, 13, 17) The Santa Ana Mountains (including the Elsinore Mountains) extend from Santa Ana Canyon southeastward a distance of 30 miles or more, with an average width of 10 miles. Still farther south these mountains merge into the Peninsular Ranges, which continue into Lower California. The highest peak of the range is Santiago Peak, which has an altitute of 5,691 feet.

Structurally the Santa Ana Mountains are a fault block, elevated along the northeast side and tilted toward the southwest. Plutonic rocks, mainly quartz diorite, are exposed along the escarpment on the northeast side and in the central part of the mountains, where there are also patches of schist, and large areas of effusive and porphyritic rocks ranging from dacite to andesite. Successively toward the southwest occur Triassic sandstone and black siliceous slate, somewhat metamorphosed; Cretaceous conglomerate and sandstone; Eocene sandstone with conglomerate layers; Miocene sandstone, conglomerate, and shale.

The Cretaceous conglomerates contain the following rock types in abundance: andesite, andesite porphyry, dacite, dacite porphyry, white and pink-to-black quartzite, black siliceous slate. Quartz-muscovite schist, quartz-orthoclase granite, quartz diorite, and vesicular basalt are represented rarely.

The Eocene conglomerates contain pebbles and boulders of various colored quartzites, chert, felsite, feldspathic porphyries, black siliceous slate, and angular fragments of Cretaceous sandstone and shale.

The Lower Miocene conglomerates contain representatives of quartzite, felsite, feldspathic porphyries, black siliceous slate, and chert, with, rarely, some of quartz diorite. The middle member, the Temblor or Topanga, contains pebbles and breccia material of glaucophane schist, probably derived from a land mass on the southwest, as suggested by Woodford (17, p. 236).

The recurrence of the same rock types in the successfully younger conglomerates forces the conclusion that all of the conglomerates are related as to source, excepting the Temblor formation. The Pliocene and Lower Pleistocene conglomerates at Burruel Point, and even Recent river gravels like those of Trabuco Canyon (No. 10, Fig. 1) resemble the older conglomerates in pebble composition. It is probable that the Cretaceous sea received as débris the surficial and hypabyssal material stripped off from a large area on the east and northeast, perhaps from the present Perris Block and San Jacinto regions; that subsequently this conglomeratic material underwent repeated cycles of erosion, transportation, and deposition, to form the greater part of the later conglomerates.

The preceding paragraphs describe the formations which crop out in the districts surrounding the Los Angeles Basin. Granite, diorite, anorthosite, pegmatite, and aplite, among others, crystallize at depth. Their exposure at the surface bears witness to the enormous quantity of material removed by erosion between the time of the Jurassic

plutonic invasion and the Recent epoch. The representation of these deep-seated igneous rocks in the successively younger conglomerates serves as a measure of the time, place, and rate of erosion of the land areas whence they came.

DESCRIPTION AND ANALYSIS OF PLIOCENE CONGLOMERATES

The evidence of *Foraminifera* is used in this paper to indicate the geologic age of the strata. Not only have *Foraminifera* proved their value for correlation purposes in the Los Angeles Basin, but they are often the only time indicators available.

REPETTO HILLS.—The best and most complete exposed section of Pliocene strata in the Los Angeles Basin occurs in the Repetto Hills. It will be described first as a type section for time reference purposes, although it contains but few conglomerates.

In this locality (Fig. 1, No. 1) the contact between the Miocene and Pliocene is marked only by a change in lithology, the sandy to diatomaceous shale being superseded by buff silt. Strata consisting of 3,500 feet of silt and four thin conglomeratic sand lenses are exposed along Atlantic Boulevard between Garvey Avenue on the north and the Southern California Edison Company's high-tension transmission line on the south. This section contains both Lower and Upper Pliocene beds. The lower 3,100 feet are of early Pliocene age and include all but the basal beds of the Repetto formation. The upper 400 feet of strata belong to the lower part of the Pico formation, of late Pliocene age.

There are three thin lenses of conglomeratic sandstone in the upper part of the Lower Pliocene. A fourth thin conglomeratic bed marks the base of the Upper Pliocene. Pebbles are not numerous in the conglomeratic sandstone lenses, but among those found and identified were representatives of white quartz-albite aplite and pegmatite, gray quartz diorite and dacite porphyry. Because of the presence of these types and because of the total absence of San Gabriel types, the source of these pebbles is thought to be the Perris Block.

Between the Lower and Upper Pliocene of the Repetto Hills there is a hiatus, represented in the basin on the west by a thickness of sediments. This hiatus is not indicated by discordance of the strata above and below the break; at least none was observed within the limited area of the exposure. The hiatus represents a diastem, as only a relatively thin sequence of beds is missing. The strata in the central part of the basin which correspond in time to the marginal diastem consist of 600–900 feet of sand and brown silty shale in about equal proportions. It is astonishing that no strata corresponding in

age to these beds were found cropping out around the perimeter of the Los Angeles Basin. Evidently the diastem marking this Middle Pliocene interval involves the entire margin of the basin of deposition.

Beds considered as Pleistocene deposits, which unconformably overlie the Pliocene strata along the south side of the Repetto Hills, consist of red-to-brown sandy conglomerate. They are non-fossiliferous and have a continental aspect. They contain quantities of pink pegmatite and aplite, pink granite, dappled diorite, quartz monzonite, granodiorite, gneiss, hornblende and bictite schist. This is a typical San Gabriel assemblage, and the material must have been supplied by that range.

LOS ANGELES CITY AREA.—Scattered outcrops in the northern part of the main business district of Los Angeles (Fig. 1, No. 2) along road cuts and excavations reveal a thickness of about 1,000 feet of Pliocene strata. Good exposures occur along the northwest side of Hill Street between First and Fourth streets, also along the southeast side of Flower Street between Second and Fifth streets, and again along Beaudry Avenue between Fourth and Sixth streets.

The base of the Pliocene section overlies layers of Miocene laminated diatomaceous shale, of a buff to nearly white color. The Pliocene strata consist of poorly consolidated buff silt. No suggestion of unconformity can be observed other than a change in character of the beds. The fossils likewise indicate a conformable relationship. Miocene *Foraminifera* and siliceous organisms mingle with the Lower Pliocene forms near the contact, then disappear. Conglomerates are absent at the contact.

Six thin beds of conglomerate are exposed immediately east of the corner of Fourth and Flower streets. The lowest is approximately 500 feet above the base of the Pliocene section. The conglomerate layers vary in thickness from 6 inches to 3 feet, and are about 10 feet apart. The conglomerates contain granules, pebbles, and cobbles, poorly to well rounded, and sedimentary breccia fragments. They apparently contain a combination of material of both short and long transportation, and the more resistant types are the better rounded. Above these conglomerate beds are several hundred feet of buff-colored silt.

The conglomerates consist predominantly of limestone fragments which occur sometimes as well rounded pebbles, usually as chips, slabs, and blocks as large as a foot in diameter. Most of the limestone has a dense texture. Individual pebbles and fragments vary in color from nearly white, through light gray, to dark buff. Many of the blocks and slabs show *Pholad* borings. Several dark reddish buff limestone pebbles contain diatom impressions. Holman, Ferrando, and

Driver (10) note the presence of numerous casts of *Valvulinaria* cf. *californica* Cushman, typical of the Lower Modelo formation, in one of the limestone pebbles. The conglomerates also contain a few poorly to well rounded pebbles and cobbles of fine-grained quartz diorite, basalt, andesite porphyry, and chert; a few fragments and pebbles of glaucophane schist; chips and slabs of buff-to-white laminated foraminiferal Miocene shale. The matrix consists of calcareous sandstone. These conglomerates are of early Pliocene age. The foraminiferal assemblages in the silts interbedded with the conglomerate layers correspond with those of the Repetto formation.

The conglomerate and breccia are believed to have originated in the Miocene strata of the Santa Monica Mountains. The limestone material is assigned to the limestone layers and lenses of the Modelo formation, the well rounded pebbles and cobbles of igneous rocks to the Miocene conglomerates, the diatomaceous shale fragments to the Upper Modelo. The glaucophane schist fragments can be attributed to an outcrop of San Onofre conglomerate on a former land mass west or southwest of the present shore line. They were no doubt washed along by shore or near-shore currents to their place of interment. The origin of the andesite and basalt pebbles presents difficulties, as these types of rock are common in many of the potential source areas. However, in view of the probable origin of the other material in the Santa Monica Mountains, they may be derived from the Miocene intrusives of that character in the same district.

GARFIELD AVENUE.—Garfield Avenue traverses a pass through the eastern end of the Repetto Hills, about ¾ mile east of Atlantic Boulevard and the Repetto section previously described (Fig. 1, No. 5). Road excavations along the sides of the avenue expose Lower and Upper Pliocene and Lower Pleistocene rocks.

Lower Pliocene beds crop out only at the northern end of the pass as far as ½ mile south of the divide. Between this point and a Southern California Edison Company power house, located about ¾ mile farther south, Upper Pliocene beds are exposed. South of the power station the strata are Lower Pleistocene. The Lower and Upper Pliocene formations are composed of light buff silt, in places sandy. Conglomerate layers are absent. The presence of *Foraminifera* indicates that the formations are marine.

Pebble counts were made from two of the more purely conglomeratic layers in the Lower Pleistocene measures immediately south of the power station. They indicate a very unusual assemblage of rocks, as 60 per cent of the conglomerate is composed of white quartz-albite pegmatite and aplite. The results of the pebble count are given below.

PEBBLE COUNT NO. 1 (230 pebbles)

Rock Types	*Per Cent*
White quartz-albite pegmatite	35
White quartz-albite aplite	24
Dacite porphyry	9
Quartz diorite	7
Quartz-diorite gneiss	6
Dacite-porphyry gneiss	4
Quartz	4
Felsite porphyry	3
Banded impure quartzite	2
Epidote altered quartz-plagioclase gneiss	2
White diatomaceous (Puente) shale	2
Biotite schist	1
Dappled diorite	1
	100

PEBBLE COUNT NO. 2 (100 pebbles)

Rock Types	*Per Cent*
White quartz-albite pegmatite (1 graphic)	38
White quartz-albite aplite	25
Dacite porphyry	14
Quartz diorite	9
Felsite porphyry	4
Quartz-diorite gneiss	3
Basalt	2
Quartz	2
Hornblende-diorite gneiss	1
Epidote altered quartz-plagioclase gneiss	1
Pink granite	1
	100

The preponderance of pebbles of white pegmatite and aplite, gray quartz diorite, feldspathic porphyries, and the absence of pebbles diagnostic of other areas, show that nearly all the material came from the Perris Block on the east. The San Gabriel area contributed very little to the sediments, as indicated by the dearth of San Gabriel types.

The Pliocene and Lower Pleistocene conglomerates contain practically no San Gabriel material from the Repetto Hills eastward to the eastern end of the Puente Hills. Its absence can not be explained as being due to differential weathering. Examination of the débris issuing from San Gabriel Canyon, and again at points 10 and 20 miles downstream, shows clearly that the pink pegmatites and aplites are as resistant to corrasion and corrosion as the white; that the pink granite and the dappled diorite are more durable than quartz diorite. The only conclusion permissible is that this material came from the Perris Block.

The extremely high percentage of white pegmatite and aplite pebbles and cobbles in the conglomerate at the Garfield Avenue locality, however, may be attributed to the selective action of weathering

and transportation. These rocks make up less than 5 per cent of the mass of the Perris Block and yet comprise 60 per cent of the conglomerates derived therefrom. The pegmatites and aplites occur as narrow dikes, crossed by numerous fractures, which cause the rock to break up into small blocks which are rapidly carried away by the streams. These rocks are also resistant to erosion, and this property likewise aids them in their survival as pebbles and cobbles. The contrary is true of the quartz diorite which makes up possibly 80 per cent of the mass of the Perris Block. It disintegrates and decomposes rapidly. The material so formed is carried away as sand, silt, and clay. When blocks of quartz diorite break off and slide or roll into the stream channels, they are usually of such dimensions that most of their bulk must be worn away by abrasion before they become small enough to be carried far by the streams. This is confirmed by the types of heavy residual minerals contained in the finer-grained sediments. They are green hornblende and biotite, with lesser amounts of titanite, zircon, epidote, garnet, and others. The dominant minerals, green hornblende and biotite, are especially characteristic of the granodiorite masses, and their abundance in the finer-grained clastic sediments points to the disintegration of the granodiorite on a large scale.

These processes, it is believed, account for the difference between the relative percentages of pegmatite-aplite and quartz diorite in the source areas and in the conglomerates derived from them. Each cycle of erosion, transportation, and deposition undergone by the pebbles in their journey to their present site would increase the ratio of pegmatite-aplite to quartz-diorite pebbles. The conglomerates at Garfield Avenue show such a degree of selection that they may have undergone more than one cycle of erosion.

The rapid alternation of sand, silt, and conglomerate, the channel-like appearance of many of the gravels, the poor sorting of the sand, and finally, the essential absence of fossils, make it probable that these strata are non-marine. They may be entirely non-marine or may have been dropped in an area repeatedly traversed by a migrating strand line. Because of their apparent non-marine character and their superposition over the marine Upper Pliocene, the early Pleistocene age of these beds is assumed.

A low line of hills, composed of reddish sand and conglomerate, trends east and west along the south side of the Repetto Hills. In this locality it is about ¼ mile south of the Southern California Edison power station. The conglomerate consists of San Gabriel material having a high content of dappled diorite, pink granite, pink aplite and pegmatite pebbles and cobbles. White pegmatite and aplite are

absent. This formation overlies the Pliocene and Lower Pleistocene strata of the Garfield Avenue section. It may be traced into similar material occurring at the south end of the Atlantic Boulevard pass. It is non-marine and is considered to be of late Pleistocene age.

PUENTE HILLS.—The Puente Hills form a conspicuous topographic ridge extending eastward from the San Gabriel River near the town of Whittier to Santa Ana Canyon and Chino Creek. Their altitude averages somewhat more than 1,000 feet. They are 23 miles long and 4–10 miles wide. The southern side of the hills has a nearly straight trend determined by the Whittier fault. The northeastern side is bounded by the Chino fault. The Puente Hills have been complexly faulted and folded.

Formations at Puente Hills.—The strata in and near the Puente Hills consist of Miocene, Lower and Upper Pliocene, Lower and Upper Pleistocene. Physical conditions preceding the Pliocene epoch are reflected in the character of the Puente formation of Miocene age, which consists of white-to-buff diatomaceous shale, sandy shale, sandstone, and conglomerate. Most of the clastic material is fine-grained. It was carried in and dropped so slowly that the large numbers of diatom tests settling out at the same time form an appreciable part of the deposits. These beds testify to neighboring land masses of low relief.

Above the Puente diatomaceous shale there is an abrupt change to coarse conglomerates, sandstone, and siltstone, with a combined thickness of more than 5,000 feet. This series is well exposed near the summit of Workman Hill, north of Whittier, also along the northwest end of the Puente Hills, where English (5, p. 40) measured and described a section consisting of 5,350 feet of this material. Approximately one-third of this section is conglomerate, the remainder sandstone and siltstone. This series is also well exposed along the entire south side of the Puente Hills, south of the Whittier Fault. A cross section made just east of the town of Whittier showed a thickness of 5,700 feet of Lower and Upper Pliocene beds. The formations are composed of alternating beds of sandstone, siltstone, and conglomerate. Lower Pleistocene beds are exposed in the low hills east and west of the Murphy Ranch headquarters. They resemble the Pliocene strata, but the pebbles in the conglomerate layers are generally smaller.

Many of the conglomerate beds are well indurated. They show a wide variation in size of material ranging from granules to boulders 2 feet in diameter. Some of the pebbles and boulders are well rounded; others exhibit the original flat sides with only the corners rounded. A count of 300 pebbles and boulders made ½ mile south of the summit of

Workman Hill (No. 6, Fig. 1), on the side of the road in Turnbull Canyon, indicates the following types of rock as composing the conglomerates.

Rock Types	*Per Cent*
White quartz-albite pegmatite	26
White quartz-albite aplite	19
Dacite porphyry	10
Quartz diorite	9
Felsite porphyry	6
Andesite porphyry	4
Vein quartz	4
Fine-grained quartz diorite	4
Felsite	3
Dappled diorite	2
Fine-grained gneissic diorite	2
Biotite schist	2
Quartzite	2
Sandstone	2
White diatomaceous shale	1
Hornblende schist	1
Unknown	3
	100

Pebbles of biotite gneiss, diabase, and gabbro are present rarely in the conglomerates but were not found in this collection. Only one pebble of pink granite was found.

The assemblage of rock types in the foregoing pebble count is remarkably similar to that of the Garfield Avenue conglomerates. It contains a somewhat higher percentage of igneous and metamorphic rocks with relatively large amounts of femic minerals, and a correspondingly smaller percentage of the white pegmatites and aplites. The pebbles and boulders high in femic mineral content are usually partly decomposed, and another cycle of erosion would doubtless destroy many of them. It is thought, therefore, that the Lower Pleistocene conglomerates were formed in part by the reworking of Pliocene conglomerates. As the two formations are conformable in the present outcrops, the Pliocene pebbles furnished to the Lower Pleistocene beds must have come from deposits nearer the margin of the basin of deposition.

Examination of the conglomerates in dozens of other localities in the Puente Hills indicates rock assemblages similar to those in the pebble count shown in the foregoing list. This statement applies also to the pebble groups found at the west end of West Coyote Hills and the east end of East Coyote Hills, and to the Upper Miocene Puente conglomerates in the San Jose Hills between Pomona and Covina (No. 8, Fig. 1). They all show a high content of quartz-albite pegmatite and aplite.

Origin.—These conglomerates represent a unit assemblage from

a single source. They originated in the northwestern part of the Perris Block area. Only three dappled diorite pebbles from the San Gabriel Range and two pink granites which may have come from that range were seen among the thousands of pebbles and boulders examined. This illustrates the negligible part played by the San Gabriel Mountains as a contributor to this series. From late Miocene to the end of early Pleistocene, the Perris Block area was shedding clastic sediments into the basin of deposition, most of the material finding lodgment in the northeastern portion of the basin.

Age.—The relationship of the conglomerate series to the underlying diatomaceous Puente formation is not entirely clear. Here and there, the two are locally unconformable. Usually they are conformable and frequently gradational in that lenses of diatomaceous shale are sometimes interbedded with lower sandstone and conglomerate. The exact contact between the Miocene and Pliocene must be left in doubt. It may be sufficient to say that at or near the end of the Miocene epoch an elevation of the neighboring land masses caused a sudden and radical change in type of deposition. The series contains *Foraminifera* of both early (15) and later Pliocene age.

A group of gravelly beds of continental aspect, which conformably overlies strata containing latest Pliocene *Foraminifera*, occupies the outermost fringe of outcrops along the south side of the Puente Hills. They resemble the conglomeratic strata described as Lower Pleistocene which are exposed at Garfield Avenue, and contain a similar assemblage of Perris Block pebbles, and chips of Puente shale. These beds are non-fossiliferous and their age is not definitely determined. However, they have a place in the stratigraphic column which is occupied by marine Lower Pleistocene in the San Pedro Hills. They conformably overlie uppermost Pliocene strata and unconformably underlie Upper Pleistocene beds. For these reasons they are believed to be continental beds equivalent in age to the marine Lower Pleistocene in other parts of the basin.

The Puente Hills conglomerate series apparently bridges the time interval from late Miocene into early Pleistocene time, although many diastems and disconformities may be present in the series, effectively concealed by the irregular bedding characteristic of coarse conglomerates.

Upper Pleistocene.—Upper Pleistocene beds unconformably overlie the earlier formations around the margins of the Puente Hills. At the west end of the hills the Upper Pleistocene strata contain San Gabriel material, as they do along the south side of the Repetto Hills. The most common pebbles and boulders are of pink granite, pink

pegmatite and aplite, and dappled diorite. In the vicinity of the eastern end of the Puente Hills, Santa Ana Canyon, and Burruel Point, the Upper Pleistocene beds consist mainly of material derived from the San Bernardino Mountains. They contain quantities of pink granite, pink pegmatite and aplite, gneisses, feldspathic porphyries, and quartzite. The Upper Pleistocene and Recent alluvium underlying the La Habra terrace, near La Habra and Yorba Linda, consists of Perris Block material reworked from local Puente Hills Pliocene conglomerates and deposited as alluvial outwash (No. 9, Fig. 1).

BURRUEL POINT.—Lower Pliocene beds are missing at Burruel Point, where Upper Pliocene strata progressively overlap the underlying truncated Miocene measures. The Upper Pliocene and Lower Pleistocene beds contain pebbles and cobbles furnished by the Santa Ana Mountains, mainly by the reworking and redeposition of older conglomerates. The pebbles contain large numbers of feldspathic porphyry, quartzite, siliceous slate, Triassic sandstone and quartzite, gray and reddish tuff and agglomerate, a little muscovite schist, quartz diorite, and chert.

COYOTE HILLS.—The East and West Coyote Hills are located a short distance west of Burruel Point. They lie south of the Puente Hills and are within the Los Angeles Basin proper. Lower Pliocene strata are absent at Burruel Point, but they underlie the Coyote Hills. Small pebbles and chips of glaucophane schist were cored in the Standard Oil Company of California's Bastanchury No. 1 at a depth of 5,522 feet, in the West Coyote oil field. The strata containing these pebbles are of early Pliocene age, as indicated by the associated *Foraminifera*.

The nearest source of this glaucophane schist is the San Onofre facies of the Temblor formation, which crops out along the southwest side of the Santa Ana Mountains. Burruel Point and the Santa Ana Mountains were emergent during early Pliocene and it is highly probable that the glaucophane schist fragments came from this source.

SAN JOAQUIN HILLS.—The San Joaquin Hills are near the southeastern end of the Los Angeles Basin, adjacent to the Pacific Ocean. Good exposures of both Miocene and Pliocene rocks are found at their western end about a mile north of Newport and Balboa, on both banks of the Newport Slough (No. 11, Fig. 1).

The lowest beds exposed are white siliceous diatomaceous shale overlain by gray, punky, carbonaceous, diatomaceous shale of Puente or Monterey age. Above these beds are three layers of sedimentary breccia, 5–15 feet apart, and 2–6 feet thick, which are angularly unconformable with the beds below. The breccia beds are overlain with

a thin deposit of brown shale, then by Lower and Upper Pliocene silt and sand.

The breccia layers contain chips and slabs of highly indurated sandstone showing *Pholad* borings and white diatomaceous shale. They also contain pebbles of quartz diorite, andesite porphyry, dark quartzite, vein quartz, muscovite schist and glaucophane schist, whale bone and whale teeth fragments, and fossil wood. The material is a mixture of Santa Ana and San Onofre types. The age of these beds is either latest Miocene or earliest Pliocene.

SAN PEDRO HILLS.—About 400 feet of Lower Pliocene strata are exposed on the north side of the San Pedro Hills. They consist of light brown silt and clay shale. Several small subangular pebbles of glaucophane schist were recovered from an outcrop of these beds in a road cut on Western Avenue (No. 4, Fig. 1) a short distance within the San Pedro Hills. The source of these pebbles is no doubt an old land mass which existed somewhere on the west or south, and they arrived at their present site by one or more cycles of erosion and deposition. Lomita Quarry also contains Lower Pliocene strata, but no pebbles were found in them.

POTRERO CANYON.—Potrero Canyon is ½ mile west of Rustic Canyon, which marks the west boundary of the city of Santa Monica (No. 3, Fig. 1). A small area of Pliocene sediments is preserved as a downfaulted block on the north side of the Coast Boulevard, within the mouth of the canyon. About 1,000 feet of strata are exposed, which consist of gray clay-shale beds, some of which are sandy, with a few thin beds and lenses of brown-to-gray limestone, and breccia beds composed of angular fragments of limestone. Hoots (14, p. 116) considers that the breccia material was derived from the reworking of exposed Miocene strata near by.

SUMMARY OF SOURCE AREAS AND DERIVED CONGLOMERATES

A summary giving the source areas and a list of the dominant rock types in the conglomerates derived from each of them follows. Some rocks are present in more than one group. The important principle in such cases is that the whole assemblage must be used in order to have diagnostic value (Fig. 2).

Santa Monica Mountains.—Sedimentary breccia composed of limestone fragments, often with *Pholad* borings; pebbles of quartz diorite, granodiorite, feldspathic porphyry, and basalt.

San Gabriel Mountains.—Pink quartz-orthoclase granite, pink quartz-orthoclase pegmatite and aplite, dappled diorite, hornblendite, and gneisses. Conglomerates derived from the western end of the

mountains contain anorthosite,—not present in the conglomerates of the Los Angeles Basin.

San Bernardino Mountains.—Pink quartz-orthoclase granite, pink quartz-orthoclase pegmatite and aplite, quartzite, feldspathic porphyry, and gneiss.

Perris Block.—White quartz-albite pegmatite and aplite, lesser amounts of light and dark gray feldspathic porphyries, gray quartz diorite.

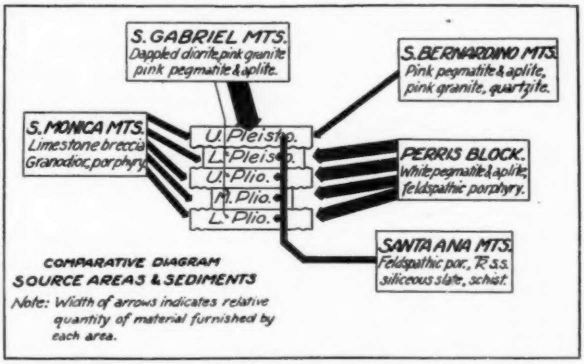

FIG. 2.—Comparative diagram, source areas and sediments. With each source area are given dominant rock types characteristic of conglomerates derived from that source.

Santa Ana Mountains.—Dark, light gray and pink feldspathic porphyries ranging in composition from andesite to latite, vari-colored quartzites from black to white, Triassic sandstone and black siliceous slate; small amounts of gray quartz diorite, schists and gneisses, and glaucophane schist from the San Onofre facies of the Temblor formation.

PLIOCENE AND LOWER PLEISTOCENE PALEOGEOGRAPHY

Pre-Pliocene events.—Pebbles in the Cretaceous formations of the Santa Ana Mountains indicate that the source areas, probably the San Jacinto and Perris Block areas, had been denuded of surficial and hypabyssal material to expose the Jurassic plutonic rocks during the Cretaceous period.

Miocene conglomerates contain pebbles of plutonic rocks from the San Gabriel and Perris Block areas, hence these had been unroofed to expose the batholithic intrusive by Miocene time, or earlier.

Near the close of the Miocene, during Modelo-Puente time, the sea was more widespread than at any subsequent time. The Ventura

Basin was connected with the Los Angeles Basin and the Santa Monica Mountains were submerged. The Miocene sea extended over the Santa Ana Mountains and San Gabriel Range to a greater extent than any subsequent sea has done.

At or near the close of the Miocene, uplift took place. The sea withdrew partially but not wholly from the Los Angeles Basin, so that deposition continued in the central part of the basin while the margins were being eroded. Sedimentation in the basin changed from diatomaceous shale to sand, silt, and conglomerate. The Santa Monica Mountains district became high land; the Santa Ana and Perris Block areas became mountainous. Burruel Point was emergent. The San Gabriel area was above the sea but had not sufficient relief to be an important source for clastic material. The Los Angeles Basin was separated from the Ventura Basin and the San Fernando Valley area by the Santa Monica Mountains, from the Imperial Valley area by the mountains on the Perris Block, and from the Mohave Desert by the San Gabriel Hills.

Early Pliocene.—When the Santa Monica Mountains became high land, the Modelo formation which blanketed them was exposed to erosion. The more resistant limestone members were broken up into breccia rubble. These fragments were washed about by the waves and currents, attacked by *Pholads* and other burrowing invertebrates which infested the littoral zone, until finally they were buried in the Pliocene sediments. The conglomerate beds of the Miocene formations were reworked and redeposited in the Pliocene sea. These breccia and conglomerate beds may now be seen in the exposures of the Los Angeles City section and Potrero Canyon. They are also believed to exist unexposed along the south side of the Santa Monica Mountains.

Outcrops of San Onofre beds somewhere on the west or southwest contributed glaucophane schist pebbles and chips to the Pliocene deposits. Some of them were carried along the shore eastward as far as the Los Angeles City area. Others were deposited on the north side of the present San Pedro Hills, which may have been a submerged high area in the Pliocene basin.

Between Burruel Point and the San Gabriel area a wide embayment of the sea basin was receiving enormous quantities of débris collected by a master drainage system from the mountains in the northern part of the Perris Block. The coarser terrestrial material was carried by waves and currents as far as the Repetto Hills, and the finer was no doubt distributed much more widely over the bottom of the early Pliocene sea floor.

The northwestern portion of the Santa Ana Mountains, being

topographically a projection into the sea, did not develop large drainage patterns, but was cut away by short streams and by wave action. It was surrounded by a fringe of locally derived conglomerate, sand, and silt.

The San Joaquin Hills may have been emergent during the deposition of the breccia and conglomerate beds along their western side. If the material in these beds was derived locally, the San Joaquin Hills must have been denuded to a depth sufficient to uncover the Temblor formation with its glaucophane schist pebble beds. The

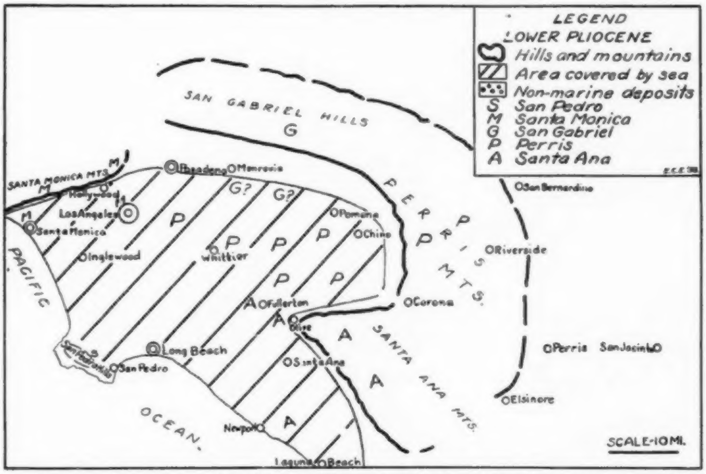

FIG. 3.—Paleogeography of Lower Pliocene. The locations of source areas and derived conglomerates are represented by appropriate letters as follows: *S*—San Pedro, *M*—Santa Monica, *P*—Perris, *A*—Santa Ana, *G*—San Gabriel.

Santa Ana Mountains could have supplied the same conglomerate and breccia material; hence the emergence of the San Joaquin Hills area at that time is open to question. Marine silt beds of definitely known early Pliocene age, which occur higher in the section, contain *Foraminifera* of a more or less dwarfed aspect characteristic of near-shore conditions. It is believed that the San Joaquin Hills area was a submerged shallow-water area during most of the Pliocene, and that a relatively thin veneer of marine Pliocene strata was laid down over it (Fig. 3).

Middle Pliocene.—Subsidence kept pace approximately with deposition, but grade was apparently attained between land and sea for an interval during the Middle Pliocene. While this condition obtained,

the clastic material brought in by the rivers passed over the edges of the basin and was deposited in the deeper water of the central part. This interval is marked by marginal diastems (Fig. 4).

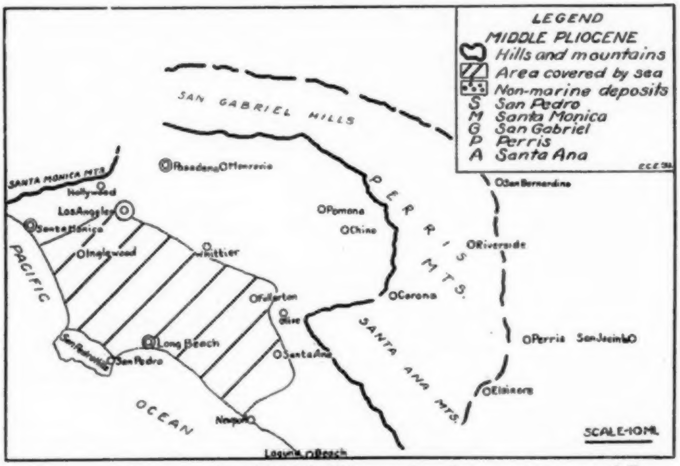

FIG. 4.—Paleogeography of Middle Pliocene. Conglomerates are essentially absent, sediments consisting of sand, silt, and shale.

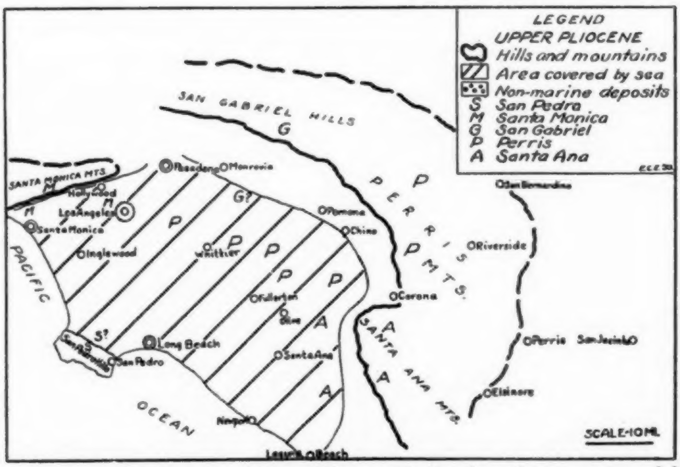

FIG. 5.—Paleogeography of Upper Pliocene. The locations of source areas and derived conglomerates are represented by appropriate letters as follows: *S*—San Pedro, *G*—San Gabriel, *P*—Perris, *M*—Santa Monica, *A*—Santa Ana.

Late Pliocene.—At the beginning of the late Pliocene, subsidence of the basin and uplift of the adjacent land areas inaugurated another period of widespread deposition in the basin. The relations between land and sea were somewhat similar to those during the early Pliocene. The Santa Ana Mountains, however, did not share as a whole in the general uplift. The western end, including Burruel Point, which had suffered much denudation during the early and Middle Pliocene, was generally submerged by the late Pliocene sea. Strata composed mainly of material derived from older formations of the Santa Ana Mountains were deposited over this area (Fig. 5).

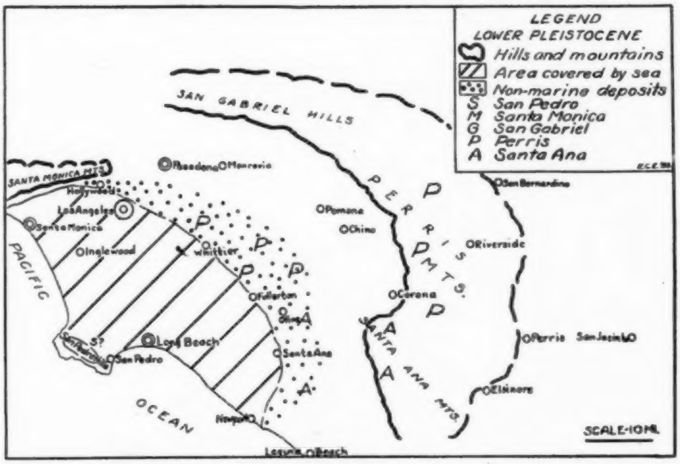

FIG. 6.—Paleogeography of Lower Pleistocene. The location of source areas and derived conglomerates are represented by appropriate letters as follows: *S*—San Pedro, *G*—San Gabriel, *P*—Perris, *A*—Santa Ana, *M*—Santa Monica.

Early Pleistocene.—The close of the Pliocene epoch was not marked by striking physiographic changes. The major cycle of erosion and deposition from one important period of uplift to the next had not been completed, but a partial withdrawal of the sea took place. Source areas were thereby rejuvenated, and terrestrial material containing assemblages of pebbles similar to those in the Pliocene strata was brought into the basin of deposition. Marginal areas which were formerly sites of marine and sub-aerial deposition, received continental deposits, some of which may now be seen along the south side of the Puente Hills. The exposed portions of the strata previously laid down were subject to erosion, reworking, and redeposition.

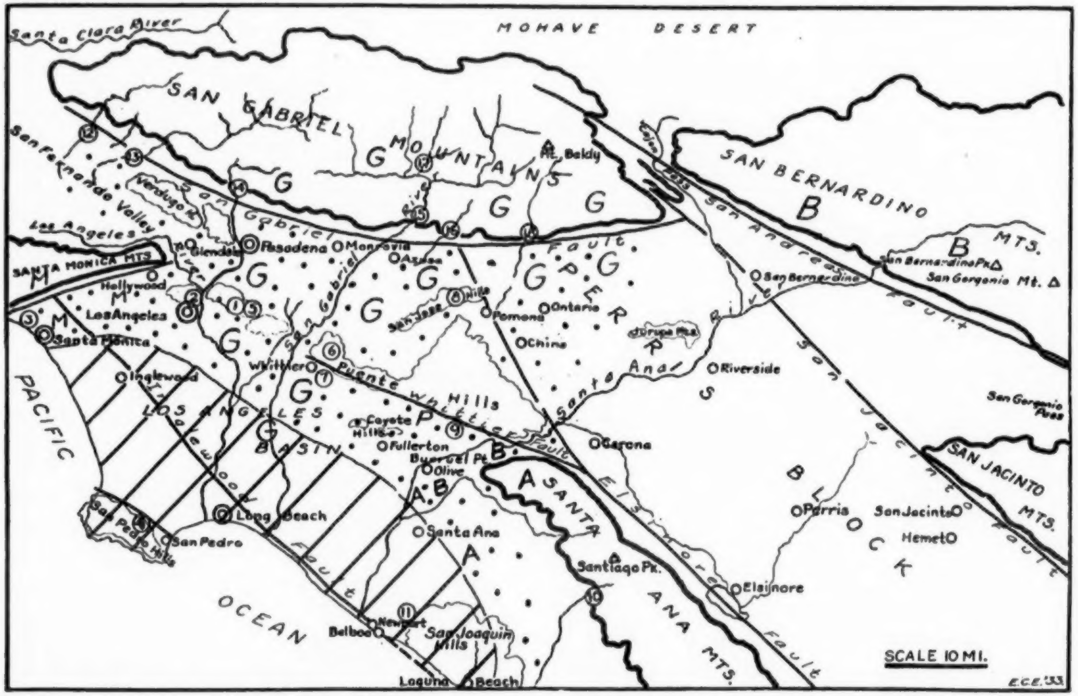

FIG. 7.—Paleogeography of Middle and Upper Pleistocene. Tectonic disturbance which caused faulting and uplift of mountains occurred mainly in Middle Pleistocene. Upper Pleistocene marine deposits are indicated by cross-hatching, non-marine by dotted areas. Locations of source areas and derived conglomerates are indicated by the following letters: *M*—Santa Monica, *G*—San Gabriel, *B*—San Bernardino, *A*—Santa Ana.

The adjacent land masses had been reduced to low or moderate relief by the end of early Pleistocene time (Fig. 6).

Middle and late Pleistocene.—In the Middle Pleistocene a diastrophic revolution occurred (7), and the present physiographic expression of southern California developed (Fig. 7). The Santa Monica, San Gabriel, San Bernardino, San Jacinto, and Santa Ana mountains were elevated, thrust upward along fault planes. (Whether the fault planes existed prior to the Middle Pleistocene was not determined.) The Perris Block, long a positive and prominent physiographic element, became depressed, overridden perhaps by the eastern end of the San Gabriel Mountains.

The Santa Ana River succeeded in maintaining its course, became an antecedent stream, and grew headward into the San Bernardino Mountains, tapping them for the first time. Enormous quantities of coarse clastic material were supplied to the Los Angeles Basin by the rejuvenated San Gabriel, Santa Monica, San Bernardino, and Santa Ana mountains. The Perris Block was at or below grade and contributed none. Alluvial fans began to build themselves outward from the mountain fronts and are still accumulating.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 6 (JUNE, 1934), PP. 813-816, 2 FIGS.

GEOLOGICAL NOTES

CRATERS FORMED BY AIR BLOWERS

Air blowers, or natural escapes of air from the soil or from a buried porous bed through restricted vents, have long been known to geologists and are familiar to many who have worked in the Gulf Coastal Plain of Texas, although there seems to be no local literature on the subject. It is said by farmers of irrigated lands that, when the water is turned on dry ground, it commonly bubbles actively as the air escapes.

The conditions necessary to produce a conspicuous air blower seem to be a porous soil which is dried out to a depth of several feet during a dry period of several weeks while the water table falls, followed by a flood of water which at once causes the top layer of the soil to seal itself over the surface of large areas, while a few vents perhaps remain open for the entrance of water and others for its issuance through confined openings. The low hydrostatic head of the flood water, with its downward compression of the soil, forces the air out at the vents that are not quickly sealed by the wetting of the soil. Clays which crack deeply in dry weather and which quickly become plastic when wet seem to furnish ideal conditions for the development of air blowers where river floods have access. Hence, flood plains and deltaic plains are common sites of air blowers. The hot summer climate of the Texas Coastal Plain and its widespread clays account for the relative abundance of air blowers here.

Another type of air blower develops where the rise of the water table into a porous or fissured air-filled stratum which is covered by a denser stratum, or whose surface is sealed, occurs in such a manner as to allow air to escape through small vents under low compression. Since the air blowers seen by the writer were observed in summer and the escape of the air was upward, it does not seem that a difference in temperature caused the air flow. Such air flows due to temperature differences occur through the mouths of some caves, as the Blowing Cave, Bath County, Virginia, a few miles west of Millboro Springs, where cool air blows out in summer and the outside air is said to flow into the cave in winter.

A few examples of air blowers in the Gulf Coast of Texas visited by the writer are given.

In Montgomery County, near Dodge, several years ago, the writer investigated two air blowers which seem to be of the class last described. At the Sandel Blower, air was reported to have come through joint clay on the top of a hill. The vent was perhaps a half inch in diameter. Twelve feet of "joint clay" which tops the hill overlies an equal amount of sand as shown in the log of a water well bored there. The top of this sand bed crops out at the base of the hill, but is mostly covered with stream alluvium. Following an unusually rainy fall and winter, air is reported to have broken out through this small vent and to have been permitted to escape at intervals through a pipe inserted in the vent by the Sandel family. A whistle placed on the pipe is said to have been audible one-fourth mile away at the residence.

Air is said to have blown from time to time from March to August in that year whenever the cock on the pipe was opened. Reports from a number of observers confirm this account.

Air is also said to have issued from the rotted tap-root of a pine sapling a few miles from the Sandel Blower where topography was similar and the formations presumably much the same as at that place. Analyses made of the air caught at both places by a local banker showed it to be atmospheric air with a slight excess of nitrogen. Gases from the decomposition of wood are said to issue, sometimes with considerable violence, when large trees are felled. In this case the gas seems to have been air, and to have come from the earth and not from the wood.

Another type of air blower is described by Baker[1] as a so-called "whistling mound" where a low rustling sound was made by air issuing through the surface of a sandy mound.

Escapes of air from clay soils of river flood plains in fairly large volumes are commonly reported. Large wash tubs are readily filled with air when inverted over these blowers and the pressure in the filled tub is sufficient to make it difficult to hold the tub in place so as to confine the air.

The only case which has come under the writer's observation in which a crater was formed in the clay by the escape of air is in the North Floodway of Rio Grande near the east line of Hidalgo County, on the north side of the south drainage ditch in the floodway, at Mile 2 East and Mile 17½ North.

Several craters seen here in July, 1933, were formed during Rio Grande floods following the hurricanes of 1932. The largest of three well preserved craters was 50 inches in diameter and 15 inches deep, formed in a silty alluvial clay (Figs. 1 and 2). An augur hole bored

[1] Raymond F. Baker, oral communication.

beside the crater showed 15 feet of this silt overlying a water-saturated sand which yielded no gas.

FIG. 1.—Air crater 51×15 inches. Dotted line shows position of near lip in foreground. Six-inch rule at distant lip of crater. Taken 6 months after formation.

FIG. 2.—Small air craters 6 months after formation.

In September, 1933, a flood following the hurricane of September 4 again filled the floodway with water to a depth of several feet. In all these floods it was reported by Tom F. Nolan, of Mercedes, that he saw great volumes of gas coming from these craters and forming "boils" which were visibly elevated on the surface of the water and made a noise heard for many yards away. No test of the inflammability of the gas was made during the height of the floods when the volume of gas was large. The volume of this gas and the size of the craters led to the assumption that it was natural gas.

The writer visited the craters while the water of this last flood still covered them to a depth of a few inches. Small lines of bubbles were actively rising from the craters and from their vicinity. A tin can was filled under water with this gas, which was then allowed to blow on a burning oiled rag. The gas did not ignite or flash and the flame of the rag was perceptibly cooled and decreased in size while the gas blew into it. The conclusion that this gas was atmospheric air was inevitable.

An air blower in joint clay a few miles north of Edna, Jackson County, illustrates the extreme exaggeration of simple earth phenomena which often occurs when these are interpreted and reported by persons not trained in scientific observation. The first report of this air blower to come to Edna was a telephone message that a blow-out had occurred, that large amounts of gas were coming up in a roadway, and that one man had been "knocked out."

When examined by the writer a few minutes after the discovery a tiny vent the diameter of a lead pencil was found in the clay of the road. The flow of air from this vent made a hiss barely audible when the ear was held close to the ground. This gas was quite odorless and its flow cooled down the flame of a match and could not be ignited.

Two men had discovered the blower. On being questioned, one said that he had leaned down to smell the gas and had felt faint. He later admitted that the faint feeling could have been caused by his leaning over while wearing a tight belt just after eating Sunday dinner. In spite of the insignificance of the flow and "blow-out" vent, these men had not attempted to light the gas for fear they would be blown up.

In the early days of the exploration of the Gulf Coast for salt domes many "boiling prairies" were visited by scouts and geologists and some of the "boils" were found to be of natural gas, resulting in the discovery of salt domes. Few observers besides geologists seem to think of testing such "boils" for the inflammability of the gas.

W. Armstrong Price

Corpus Christi, Texas
April 2, 1934

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 6 (JUNE, 1934), PP. 817-820, 1 FIG.

DISCUSSION

THICKNESS AND DEPTH OF STRATA[1]

The problem of the determination of the thickness and depth of strata, although relatively simple from the mathematical standpoint, seems to have had less careful treatment by textbook writers and less uniformity of usage among field geologists than almost any other simple problem of stratigraphic geology.

Oil geologists are accustomed to working in beds of such low dip that thickness and depth are synonymous. When, however, they encounter the problem of making accurate stratigraphic measurements in beds of appreciable dip they must find a suitable formula. It seems either that tastes in the choice of formulae vary widely, or that the inadequate treatment of the problem in reference books and its scattered bibliography lead geologists to develop their own formulae or to use the first which come to hand.

Formulae developed upon a special occasion (Ickes, 1934),[2] though doubtless of general application for those to whom integration and "direction cosines" seem simple affairs, are given by Ickes, who states that he is presenting the simplest of those then worked out. Ickes does not compare these formulae with other forms in use for the same problem, and presents no bibliography. Hence, the writer is not prepared to say whether or not Ickes' formulae, once mastered, would be simpler in application and operation than others. But, for those geologists who, like the writer, have long since become extremely "rusty" in their use of mathematics—and this must be a large class—Ickes' demonstration is unnecessarily complicated and the much simpler, yet wholly adequate, two-dimensional trigonometric solution seems preferable.

A simple trigonometric solution of the problems of the determination of thickness and depth in inclined strata has been published by the writer (1922). This presentation, which is reproduced herewith, has been condensed to the simplest form found after extended use by several geologists,[3] especial attention having been given to ease of recording of, and computation from, the notes and the ease with which the formulae and the diagrams may be retained in the memory. After a season's use of these formulae it is possible readily to reproduce them from memory, even after the lapse of years. The writer's formulae follow.

[1] Discussion of E. L. Ickes' paper, "Formulas for Calculating Stratigraphic Thickness Exposed Between Two Dips," this *Bulletin*, Vol. 18, No. 1 (January, 1934), pp. 139–42.

[2] Dates, or authors' names with dates, in parentheses refer to entries in the accompanying bibliography.

[3] The formula for thickness and the notebook form were obtained by the writer from Charles K. Swartz, Johns Hopkins University, and were used by members of the Maryland Geological Survey for the measurement of stratigraphic sections of considerable length under a variety of topographic conditions in the Appalachian Paleozoic. For the mathematical proof see the original article (Price, 1922).

General formulae for thickness and depth:

Thickness = Horizontal sin $\theta \cdot$ sin Dip $\pm$ Vertical cos Dip
Depth = Horizontal sin $\theta \cdot$ tan Dip $\pm$ Vertical
(θ = angle between traverse and strike) (Fig. 1, B)

RULE: When the dip of the beds and the slope of the ground are in the same direction (ground slopes *with* dip; dip and slope angles in same quadrant) the altitude correction (Vertical) is negative (−) (Case II, BC, Fig. 1, A).

RULE: When the value of Thickness is negative (−) the traverse has *descended* stratigraphically between the two stations involved (slope angle is greater than dip). Here, the geologist has logged the bed traversed, but may be about to ascend through it again, if slope changes (Case II, BC, Fig. 1, C). A negative sign for a "depth" value indicates a height measurement, that is, the horizon of the stratum plane whose "depth" was to be determined lies overhead.

Use of slope measurements:

Given slope angle,
For *Horizontal* substitute: *Vertical cot Slope*
For *Vertical* *Horizontal tan Slope*
Given slope distance and slope angle,
The formulae become:
Thickness = Slope Distance sin $\theta \cdot$ sin (Dip $\pm$ Slope Angle)
Depth = Slope Distance sin $\theta \cdot$ sin (Dip $\pm$ Slope Angle) $\cdot$ sec Dip

The features of the writer's formulae which follow out the requirements of simplicity and ready memorization are the following.

1. Trigonometric solution of right triangles.
2. Two-dimensional diagrams[4] (derived by considering all horizontal distances as being reduced to a plane perpendicular to the strike, although making the actual reduction a part of the formula).
3. In the formulae, words (instead of letters) are used to designate lines and angles.
4. Use of horizontal distances and vertical altitudes. (Because these have more general application than slope elements. Use of slope elements when practicable.)
5. Headings for notebook columns (Price, 1922; p. 377, Table I) placed in same order as that of elements in formulae.
6. A single general formula for thickness and one only for depth, with presentation of special (simplified) cases.
7. A simple rule for determination of algebraic sign of the second term of the formulae ("altitude correction").
8. Reduction of operations to an unvarying routine and elimination of necessity of handling each thickness computation as a separate geometrical problem.

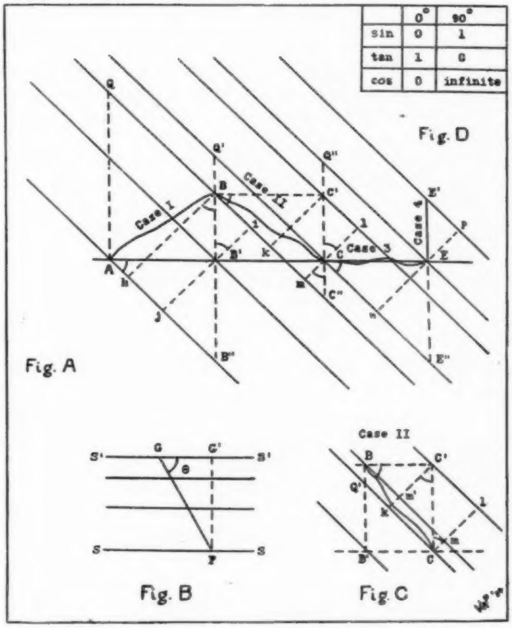
For those who prefer the three-dimensional diagrams and coördinate system of Ickes' formulae, he has fully developed the necessary accessories, including table of signs and columnar table for recording the measured elements. The writer has not checked the mathematical accuracy of his demonstration.

In most textbook developments of the formulae for thickness, slope measurements are used exclusively or are given as preferable (Hayes and Paige, 1921, p. 32). The selection of the method of surveying depends on such factors as time and funds available, number of assistants, instruments used, topographic relief, vegetation, distance between exposures, thickness of the bedding and variability of the lithology. These factors will also determine whether slope distances and slope angles will be used or whether horizontal and vertical measurements will be made. The greater the topographic relief, the more open the country, the thicker the units to be measured (up to a

[4] Figure 41, c, p. 373 (Price, 1922) should be designated as an example of Case II, as in Fig. 1, C, herewith.

limit), and the more accurate the angular measurements permitted by the instruments used, the more desirable it will be to use slope elements.

The attempt to make many short measurements with a tape, holding it at an inclined angle supposedly normal to the dip, introduces constant errors and is to be avoided. The same is true of Hewett's method of hand-levelling by sighting down the dip (Hewett, 1920; Lahee, 1931, p. 402, Fig. 346). When



Figs. 1, A and C are drawn in a vertical plane; Fig. 1, B in a horizontal plane.

Traverses are shown by solid lines (*AB*, *BC*, *CE*, *EE'*, and *GF*).

Strike lines (Fig. 1, B) are marked *SS* and *S'S'*.

Each traverse distance is multiplied by sin θ before the diagrams Figs 1, A and 1, C are used.

Inclined strata are represented by parallel solid lines which are the traces of their contact planes with the (vertical) plane of the drawing.

The thicknesses to be determined by formulae are:

$$Bh=Bj+iB;\ Cm=Ck-1C;\ En;\ Ep.$$

Fig. 1, D shows the functions for 0° and 90° for use in such special cases as Case 3 and Case 4, Fig. 1, A.

measuring slope angles with a telescopic instrument or other clinometer it is important to read the angle upon a rod or target at the same height above ground as that of the focal point or eyepiece of the instrument. The slope line and angle thus measured may, then, properly be considered to have been measured from the outcrop at the ground vertically under the instrument to

that at the base of the rod. Unless the "height of instrument" is thus used to sight upon, it would be necessary, in each case, to determine what outcrops are represented by the ends of the slope line by sighting down the dip from the instrument to the ground—a procedure which would introduce errors. Measurement of slope angles requires accurate instruments and observations and should, for accurate work, be checked by closed traverses.

In using even the simplest form of the thickness formulae it is necessary to perform many multiplications, taking much time and introducing many opportunities for error, even with the use of the usual engineering slide-rule. To avoid these objectionable features Palmer (1919) and Mertie (1922) have developed diagrams which permit the solutions to the problems of thickness and depth to be read off with the aid of a straight edge. Mertie also developed a slide-rule with concentric discs (1922), but this has not been manufactured. These diagrams of Mertie's are reproduced by Hayes and Paige (1921).

The drawback to the use of Mertie's charts—which are the most complete and general yet published—is that they require the use of slope measurements. In order to use horizontal and vertical measurements, or to combine slope measurements with these, he presents another diagram, by means of which the horizontal and vertical measurements may be used to derive slope elements, which are, in turn, used in the thickness chart. However, even with two chart operations, time may be saved in computing thickness and depth by the use of these charts because of the attendant elimination of many multiplication operations.

It is believed that the shortest and simplest way of calculating stratigraphic thickness or depth to a stratum is to be found in the use of the writer's general formulae, with his notebook form, using Mertie's charts instead of the usual engineer's slide-rule.

The following bibliography is not exhaustive. It contains ten entries, including references noted in this article. Those marked with an asterisk (*) have not been re-examined in the present connection. The literature of graphic solutions of geometrical problems of geology is much more extensive than the list here presented.

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W. ARMSTRONG PRICE

CORPUS CHRISTI, TEXAS
April 17, 1934

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 6 (JUNE, 1934), PP. 822-830

REVIEWS AND NEW PUBLICATIONS

Proceedings World Petroleum Congress (London, 1933), Vol. I (1934), "Geological and Production Series." Edited by A. E. Dunstan and George Sell. 592+xxiv pp., illus. Cloth. 9×11.25 inches. Address, Joint Editors, World Petroleum Congress, Aldine House, Bedford Street, London, W. C. 2. Price: to members of the Congress, £1, 10s; to non-members, £1, 15 s. Non-member price, through W. S. Malloy, 9–10 Bridge Street, New York, $8.85 plus 25 per cent duty.

The Proceedings of the World Petroleum Congress, held in London July 19–25, 1933, have just been published in two volumes. Volume I includes the papers given at the Congress in the geological and production sections, and Volume II includes papers in the refining, chemical, and testing section. Each paper has a summary in English. Many papers included in Volume I will be of interest to readers of the *Bulletin*, and the following brief summary will merely serve as a guide to let the reader know what is available.

The papers are grouped under the following main headings.

Geological Section
- Geological Significance of the Regional Distribution of Oil Fields
- Modern Developments in Geological Exploration
- Part I. Geophysics. Part II. Other Methods
- Geological Aspects of Oilfield Development

Production Section
- Drilling
- Production
- Transport and Storage of Oil

General
- Speech by Sir John Cadman, "Science in the Petroleum Industry"
- Speech by J. B. Aug. Kessler, "Rationalization in the Oil Industry"

The papers under the first heading are divided according to regions, the first part being on Persia, "Source Rocks of Persian Oil" by Lees; India and Burma, "Structure and Distribution of Oil-bearing Rocks," by Cotter, and "Geology of the Oil-bearing Regions of the Chindwin-Irrawaddy Valley"; and Australia, "Oil Occurrences" by Woolnough. The second part deals with Europe, with papers on the German oil fields by Kraiss, Moos, Deubel, and Schleh in German and one in English by Romanes; also a paper on "Oil in Austria" by Waagen in German, and one on Albania by the Italian company A.I.P.A., in Italian. There are also two papers on oil in western Canada by Hume and Hunter, and two general papers, one by Wade on the "Distribution of Oilfields from the Viewpoint of the Theory of Continental Spreading," and one by Professor Illing on the "Fundamental Principles Governing the Distribution of Oilfields." The discussion which followed the reading of these papers is included, and is a valuable addition.

The geophysical papers under the second heading, Part I, are arranged

under the following heads: Magnetic Method, Electrical Methods, Radioactive and Thermal Methods, Gravitational Method, Seismic Method, and Methods in Combination.

Under Magnetic Methods, van Weelden has a paper on "Magnetic Anomalies in Oilfields," and Reich and von Zwerger have papers on magnetic work in Germany.

Electric Methods include "Structural Investigations by Electromagnetic Methods" by Sundberg and Hedström, a paper in German by Belluigi of Italy on progress in electrical research for petroleum and one by Weiss on limitations of geophysical methods and new possibilities by an electrochemical method for determining geological formations at great depths. This is followed by two papers in German on radioactive methods by Ebert and Ostermeier, and one on the significance of underground temperatures by M. W. Strong.

The Gravitational Method includes a paper on the torsion balance in oil prospecting, by Templeton, and general torsion-balance papers by Vajk and Rainbow, and papers in German on North German salt domes by Breyer and Kaselitz.

The Seismic Method is covered by Goldstone in his paper on mapping by reflection waves, and Jones in his "Seismic Method of Mapping Anticlinal Structures." Ambronn has a paper in German describing the special type of seismograph which he has perfected.

The geophysical section concludes with four papers of a general nature in which several methods are involved. These include van Weelden's paper covering geophysical work in the Wichita-Arbuckle region and Fossa-Mancini's on geophysics in the Argentine, and Belluigi's on the geophysical work carried out by the A.G.I.P. in Italy, also a general paper in German on geophysical research, by Barsch.

Part II, under the heading "Modern Developments in Geological Exploration," includes the following subjects: Airplane Reconnaissance and Photography, The Aneroid Barometer in Reconnaissance Work, and some papers on applied geology. The airplane mapping article, "Some Fundamental Aspects of Air Survey" by Lieut. Salt and the two papers by Woolnough on aerial surveying in Australia, are interesting contributions. Zuber also has a short paper on the use of aerial photographs for geological purposes. The paper on the use of the aneroid barometer is by Sutton Bowman. The miscellaneous papers in this section are as follows: Beeby-Thompson's "Economic Value of Surface Petroleum Manifestations," Zuber's "Outcrop of Oil-bearing Strata," Evans' "Graphical Representation of Heavy Mineral Analyses," Hagerman's "Lithologic Methods for Determination of Stratigraphic Horizons," and two papers in German, one on subsurface studies in the Nienhagen oil field of Germany and one on petrographic studies of oil sands by Runge. Nutall has a paper on the "Application of Micro-Paleontology to Petroleum Geology," and includes a separate chart showing the range of the more characteristic *Foraminifera* in the Tampico embayment. The last paper in this section is in French, by Chahnazaroff of Jugoslavia, and deals with the construction of geotechnical subsurface maps, which are prepared to give drillers expectable well depths to any particular horizon.

The third section on Geological Aspects of Oilfield Development includes a paper on general oil-field development by Abraham, and one on the location

of wells in respect to structure, by Versluys. Chahnazaroff has also a paper in French on gas phenomena based on his studies in the Comodoro Rivadavia field. Two papers deal with unit development, one by Umpleby and one by Southwell. Nowels has a paper on "Rejuvenation of Oilfields by Natural and Artificial Flooding." Papers in the last part of this section are concerned with identification and interpretation of cores, by Sansom and Evans; tests and properties of oil sands, by Fancher, Lewis, and Barnes; the use of ultraviolet light to detect crude oil, by Bentz and Strobel; a pictorial method of recording water analyses, by Corps; and two papers on electrical coring, by the Schlumbergers and T. Sutton Bowman.

The Production Section will perhaps be of rather less interest to readers in the United States, but it gives valuable information on drilling and producing methods employed in other countries.

Papers on pressure-drilling methods employed in Persia, Burma, and Iraq are given by Seamark, Ellis, Moon, and Scott. Some of these have already appeared in oil journals in the United States.

Drilling mud is discussed in papers by Abraham, Strong, and Singleton, and cement and cementing by Reid and Parsons.

Deviation and well-surveying methods are dealt with by Evans and Abraham, and an electromagnetic teleclinometer and dipmeter is described by the Schlumbergers and Doll. Comparative strengths of rotary drill pipe and tool joints are covered by Dawson.

The production papers deal with sources of energy in moving oil, by Versluys; gas-oil ratios and saturation pressures, by Pym and Comins; surface tension and specific gravity of crude oil under reservoir conditions, by Jones; relation of reservoir conditions and rate of production, by Matheson; control of flowing production, by West; relationship of rate of production, gas-oil ratio, and ultimate recovery, by Gardescu; also papers on raising of oil, including gas-lift and pumping by Walling, Shaw, Marsh, Cuthill, and Durward, and the treatment of oil emulsions by Van der Minne.

Transportation and storage of oil is dealt with in a pipeline paper by Woodhouse, Clark, and Nash, one on line pipe by Stewart, and one on evaporation losses by Larson. Pheiffer also has a paper on pickling wrought iron and steel by means of phosphoric acid, and May deals with safety devices for the storage of inflammable liquids.

Volume I concludes with the speeches of Sir John Cadman and Mr. Kessler, and the report on the banquet with text of the speeches.

W. P. HAYNES

LONDON
March 29, 1934

Die Orogentheorie. By L. KOBER. Gebrüder Borntraeger, Berlin (1933). 184 pp. (incl. 8 pp. bibliography), 50 figs. Size, 6×9 inches. Price: paper, 14.80 RM.; cloth. 16 RM.

In this book Kober sketches in bold lines the coherent hypothetical picture he derives from a synthesis of important facts bearing on the diastrophic evolution of the earth's crust since the Cambrian. The essence of his views may be summarized without comment as follows. (Page numbers refer to the original. Quotations translated by the reviewer.)

As a result of pre-Cambrian evolution, the earth's crust at the beginning

of Paleozoic time presents the picture of a mosaic: rigid masses, the "kratogens," separated by weak, readily-folded belts, the "orogens," their width measured by thousands of kilometers. Most of Greenland plus the Canadian shield plus the central Paleozoic platform of the United States represent one such "kratogen," the Fennoscandian shield plus the Russian platform another, and the Siberian plateau lands a third. The spaces between them are the orogens.

Kober says expressly: "In the orogen the structure of the Earth's crust differs fundamentally from that of the kratogen. The orogen represents a specific field of action of the evolutionary processes ('Evolutions-Feld') of the Earth" (pp. 27–28).

Since early Paleozoic time, the orogens have suffered compression periodically in essentially world-wide epochs of orogenesis, in the sense of Stille's "Orogenes Zeitgesetz" (pp. 79–83). According to European custom, the numerous orogenic epochs are thought of as parts of three major orogenic cycles designated as "Caledonic" (early Paleozoic to end of Silurian), "Varistic" (post-Silurian Paleozoic), and "Alpinic" (Mesozoic and Cenozoic) (p. 15). Each of these three cycles begins with a "geosynclinal phase" and ends with an "orogenic phase." In the former the geosynclines of the orogens function as wide and long marine basins, "langgestreckte Meeresräume." "In the orogenic phase the evolution is reversed. It turns into a revolution. The bottom of the sea becomes a far-flung belt of mountains, solid, rigidified land. The centripetal tendencies of the geosyncline are turned into the centrifugal evolutionary tendencies of the orogen" (p. 8).

In each of the major cycles, stretches of newly folded and thereby rigidified land were added to the kratogens, slowly changing the face of the earth. Thus at the end of the Caledonic cycle, three of Kober's original ten "kratogens" are fused into one to form Africa, and several others have been enlarged by wide additions. At the end of the Paleozoic two kratogens are welded into the huge Eurasian block (without the peninsula of India), and eastern North America and Australia are completed by wide additions, leaving only the relatively narrow geosynclines of the Mediterranean and circumpacific belt for post-Paleozoic evolution.

The essence of this evolution is a growth of the kratogens at the expense of the orogens. "All orogenic evolution lasts until complete rigidification has been achieved." All diastrophism is the result of the struggle for space in the inert outer crust which is forced, "sucked," down by the gravitative field of force of the shrinking core of the earth.

Nothing like the large continental masses of to-day existed in earlier times. "In the sense of the orogen-theory, the law of continental growth is fixed with absolute certainty: the major continents of the present have originated from the separate minor continental units of the past" (pp. 9–10). In the geologic future, the struggle for space must proceed on a larger scale, with larger kratogens fighting for space.

The unified large ocean basins of to-day are likewise a new development, since much of the ocean water was taken up before by the wider geosynclines.

Structurally, orogens and kratogens reflect different responses to earth stresses. Orogenic deformation results in "decken structure." "Today no mountains are left in which the geologist with modern training would not discover 'decken,' insofar as he is concerned with deciphering their orogenic

structure" (p. 36). The "decken" are developed fan-wise between the vise-like squeezing of opposed kratogens, being overthrust outward onto the edges of the kratogens. Kober believes the pattern of the Alps to be typical, repeated essentially in all orogens. The type consists of two branches ("Stämme"), surrounding a central less deformed area, the "Zwischengebirge." Each branch shows three divisions: an outer belt of unmetamorphosed folded sediments (the "Externides"), a belt of intense metamorphism (the "Metamorphides"), and an inner belt of different facies, little altered (the "Centrides"), which adjoins the Zwischengebirge.

Orogenic movements are flow-movements on a large scale. With depth, tectonic and magmatic movements grade into each other. Remelting of crustal materials produces essentially acid magmas of "Pacific" type, especially granodiorites. Magmatic gases rise. Gneissification takes place on a large scale. In a sense, the orogens function thus as avenues of escape of subterranean heat toward the surface. "Im Orogen entgast das Erdinnere" (p. 29).

Just as the tangential yielding of the orogens is the result of their tendencies to yielding by flow, so the radial (vertical) movements which characterize the kratogens are the expression of their rigid, solid character. Kober actually uses "kratogenic deformation" as a synonym for fracturing and vertical displacement, and "orogenic" deformation for horizontal movement, deformation by folding, low-angle thrusting, and flowage. Volcanism produces rocks of "Atlantic" type.

Within an orogen, at the end of an orogenic cycle, when rigidification has been accomplished, and similarly in the belts of kratogens adjoining the orogens, "kratogenic" deformation produces "horst" and "graben" structure, which reaches its greatest relief in the basin and range structure of the central Asiatic region between the "Alpinide" ranges of the Himalayas and Lake Baikal. Combined with local folding, the transition type arises of what Stille called "Germanide" or "Saxonian" deformation.

On an even larger scale, "kratogenic" deformation leads to the splitting asunder of continents as in the East African rift belts, and in the rise and collapse of continental surfaces. The latter Kober designates respectively as "epeirogenic" and "thalassogenic" movements.

Large portions of the present-day sea floor owe their existence to such a "collapse." Where portions of the Mediterranean lie between disconnected parts of the Alpine orogen, Kober says "it is absolutely certain, that here orogenic and kratogenic (i.e., forelands) parts have collapsed." "Sialic crustal fragments of the same composition as the coasts and the islands make up the floor of the Mediterranean Sea" (p. 108).

Stille's term "undations" is applied to the regional vertical oscillations of portions of the earth's crust. "Undations" on the largest scale determine the superficial contrast between "continents" and "oceans." Structurally, the ocean basins, like the continents, consist of a mosaic of rigid masses, "kratogens," and "orogens." Thus Kober compares the northwest-southeast trending zone of the Pacific Islands, from the Ladrone to the Tuamotu islands, with a width of more than 3,000 kilometers, with the old orogenic belt of Central Asia from the Himalayas to Lake Baikal, of similar width. In each, deep basins alternate with high ranges, the latter forming the islands in the Pacific. In each, the most recent, "Alpinide" zone, with decken-structure, forms but a fraction of the whole (New Guinea and New Zealand in the Pacific).

The large areas in the northern and southern Pacific, which are devoid of islands, Kober interprets as formed by rigid masses, "kratogens." Similarly, Kober considers portions of the Atlantic, Arctic, and Indian oceans as orogens in two of which folding has produced ridges which are largely submarine. The island-bearing ridges in the Indian Ocean he considers as the counterpart of the Ural, and the mid-Atlantic ridge as the western equivalent of these two. The familiar contrast between the structural character of the Atlantic and Pacific coastlines, Kober explains by saying that, in contrast to earlier times, in the Atlantic of our day the orogens lie submerged and the kratogens form the coasts, while in the Pacific the opposite is true.

Kober supplements this generalized map picture of crustal evolution with hypothetical vertical sections of the crust drawn for each of the continents and the major oceans. For each region the structural plan is reduced to the simplest terms possible in what Kober calls "tectonograms." Thus the tectonogram for North America shows an eastern fan-shaped orogen, of which only the western branch, the Appalachians, moved westward, lies above sea-level. The eastern branch with its hypothetical kratogenic foreland lies hidden beneath the Atlantic. The western mountains form a second, "Alpenide" orogen. The eastern branch, moved eastward, forms the Rocky Mountains. The western branch, moved westward, is separated from it by the "zwischengebirge" of the Great Basin. The tectonogram of Europe shows more detail and is, correspondingly, more instructive.

The tectonograms also illustrate a further important part of Kober's hypothesis. In each orogen, the shortening of the crust is achieved by expelling matter upward near the surface, and downward along the lower part of the crust. The portion of the crust that is forced downward, the "Verdrängungskörper," bulges down into the subcrustal basaltic substratum, down to the "Simatische Ausgleichstiefe." In the core of the orogenic belt, granitoid and, farther down, basaltoid magmas arise and between, a "mixed zone."

Kober believes that final rigidification is achieved when all the matter of an orogen has been squeezed out, in decken on the surface, in a thick "Verdrängungskörper" below the crust, the opposite sides of the kratogen vise having been brought into contact (p. 75).

Throughout the book, Kober's concepts are descriptive, based on actual and inferred structural and morphologic features of the face of the earth. No attempt is made to enter into specific mechanical explanations. Nothing is said as to why or in what way the orogens differ fundamentally from the kratogens in their structure. The earth's surface is said to rise and fall alternately, to "breathe," leading in its largest aspect to the contrast between geosynclinal and orogenic phases. These oscillations of the Earth's crust are described as reflections of larger processes of the depths, especially within the "magma zone." "This, too, breathes, rises, falls, solidifies, cools, melts again. These are tidal movements within geologic time, perhaps of endogenic, perhaps of exogenic nature," that is, caused from within or from without (p. 79).

All diastrophism is viewed as ultimately due to "physiological" processes of the Earth's body, emission of gases, condensation, "progressive simatization" of the core, "corification" ("Verkernung").

The weakness of the work lies in a certain vagueness of most concepts and in the unqualified, dogmatic form of most statements. Its strength lies in the subordination of detail to the end of working out the bold outlines of a

possible picture of the whole of diastrophism sharply focused in one mind, and in its intense, often almost prophetic language. It is the only scientific German book known to the reviewer in which sentences less than one line in length are not rare and sentences not more than two lines long are common.

Kober's work deserves careful study. "The theories of others follow different lines, arrive at different pictures of crustal evolution. The more such attempts at syntheses we have, the wider grows the field of vision, by which we grasp relations" (p. 149).

WALTER H. BUCHER

UNIVERSITY OF CINCINNATI
April 18, 1934

RECENT PUBLICATIONS

AFRICA

"The Geology of British Somaliland," by W. A. Madfadyn. Part I of *Geology and Palaeontology of British Somaliland*. Published by the Government of the Somaliland Protectorate (June, 1933). Copies obtainable from the Crown Agents for the Colonies, 4, Millbank, London, S. W. 1. 86 pp., 4 pls., colored map in pocket. Paper. Size, approx. 7.25×9.5 inches. Price, 12s. 6d. net.

COLORADO

"Geology of the North and South McCallum Anticlines, Jackson County, Colorado, with Special Reference to Petroleum and Carbon Dioxide," by J. C. Miller. *U. S. Geol. Survey Circ. 5* (1934). 27 mimeogr. pp., 2 pls., 1 fig. Free.

COSTA RICA

"Stratigraphie und Tektonik des Hochlandes von Costa-Rica" (Stratigraphy and Tectonics of the Highlands of Costa Rica), by Wilhelm Lohmann. *Geol. Rundschau* (Gebrüder Borntraeger, Berlin), Vol. 24, No. 1 (1934), pp. 10–26; 1 table; 1 map.

FRANCE

Les ressources minérales de la France d'outre-mer (Mineral Resources of the French Colonies). I (1933) "Le Charbon" (Coal). Papers on production and consumption of coal; stratigraphy; tectonics. North Africa, by L. Clariond. Madagascar, by F. Blondel. French Indo-China, by F. Blondel. 245 pp., 33 figs. 6.5×10 inches. Paper. Price, 24 francs. II (1934) "Le Fer," et cetera (Iron, Manganese, Chromium, Nickel, et cetera). 436 pp., 59 figs. 6.25×9.75 inches. Paper. Price, 36 francs. Publications of Bureau d'Études Géologiques et Minères Coloniales. (Soc. d'Editions géographiques, maritimes et coloniales, 17, rue Jacob, Paris VIe.)

GENERAL

"The Microscopic Determination of the Nonopaque Minerals" (2d ed.), by E. S. Larsen and Harry Berman, *U. S. Geol. Survey Bull. 848* (1934). In this edition the tables for the determination of minerals have been brought up to date by more than 500 new entries and 100 changes in old entries. Supt. of Documents, Govt. Printing Office, Washington, D. C. Price, $0.20.

Plant Life Through the Ages, 2d ed., by A. C. Seward. Cambridge Univer-

sity Press, Oxford, England (1933). 603 pp., 140 figs. 6×9 inches. Cloth. Price, $8.00.

1934 Year Book of the National Oil Scouts Association of America. Approx. 200 pp. on 1933 activities of oil industry in Texas, New Mexico, Louisiana, and Arkansas. Send check for $5.00 to C. O. Falk, Box 1084, San Antonio, Texas.

"Bibliography of North American Geology, 1931 and 1932," by J. M. Nickles. *U. S. Geol. Survey Bull. 858* (1934). ii, 300 pp. Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $0.25.

Petroleum Production Engineering. Oil Field Development, 2d ed., by Lester Charles Uren. McGraw-Hill Book Company, Inc., New York (1934). 53 pp., 258 figs. Cloth. 6×9 inches. Price, $5.00.

On account of the unexpectedly large demand for the Guidebooks of the 16th International Geological Congress, it has been decided to reprint them. Orders should be *sent, with accompanying remittance,* to the General Secretary, 16th International Geological Congress, U. S. Geological Survey, Washington, D. C., but checks or money orders accompanying the order should be *made payable to the Treasurer,* 16th International Geological Congress (money orders made payable at Baltimore, Md.). Following is a list of the guidebooks, with the prices at which they may be obtained.

1	Eastern New York and Western New England	$0.30
2.	Mining Districts of the Eastern States	.30
3.	Southern Appalachian Region	.45
4.	Paleozoic Stratigraphy of New York	.25
5.	Chesapeake Bay Region	.25
6.	Oklahoma and Texas	.35
7.	Geomorphology of the Central Appalachians	.20
8.	Mineral Deposits of New Jersey and Eastern Pennsylvania	.25
9.	New York and Vicinity	.35
9a.	The Catskill Region	.25
10.	Southern Pennsylvania and Maryland	.25
11.	Northern Virginia	.20
12.	Southern Maryland	.15
13.	Western Texas and Carlsbad Caverns	.20
14.	Ore Deposits of the Southwest	.30
15.	Southern California	.30
16.	Middle California and Western Nevada	.30
17.	Salt Lake Region	.30
18.	Colorado Plateau Region	.20
19.	Colorado	.40
20.	Pennsylvanian of the Northern Mid-Continent Region	.15
21.	Central Oregon	.15
22.	The Channeled Scabland	.20
23.	The Butte Mining District, Montana	.20
24.	Yellowstone-Beartooth-Big Horn Region	.25
25.	The Black Hills	.20
26.	Glacial Geology of the Central States	.20
27.	Lake Superior Region	.25
28.	An Outline of the Structural Geology of the United States	.20
29.	Stratigraphic Nomenclature in the United States	.30
30.	Baltimore & Ohio Railroad	1.00

GEOPHYSICS

Lehrbuch der angewandten Geophysik (Textbook on Applied Geophysics), by Hans Haalck. Gebrüder Borntraeger (Berlin, 1934). 376 pp., 142 figs., 6 pls. 6×9 inches. Paper, 24 RM.; cloth, 26 RM.

"Bibliography of Seismology, October, November, December, 1933," by Ernest A. Hodgson. Publication of the Dominion Observatory (Ottawa, Canada, 1934), pp. 339–68. Price, $0.25.

GERMANY

Öl und Kohle (Oil and Coal). A journal in the sphere of mineral oil, bitumen, tar, and related material. The official organ of the German Society for Exploitation of Mineral Oil (Deutsche Gesellschaft für Mineralölforschung), edited by Professor L. Ubbelohde. Contains some articles and notes in the field of geology. Vol. 2, No. 1 (January 31, 1934), 36 pp. 8.25×11.5 inches. Verlag Mineralölforschung, Berlin W. 8, Jägerstrasse 61. Subscription (12 months), 11 RM.

"Die Paläeogeographie des nordwestdeutschen Lias, vom erdölgeologischen Standpunkt aus Betrachtet" (The Paleogeography of the Lias of Northwestern Germany, from the Viewpoint of Petroleum Geology), by K. Fiege. *Petrol. Zeits.* (Berlin), Vol. 30, No. 14 (April, 4, 1934), pp. 1–7; 4 figs.

PENNSYLVANIA

"Gas and Oil in Potter County, Pennsylvania," by S. H. Cathcart. *Pennsylvania Topog. and Geol. Survey Bull. 106* (1934). 31 pp., 3 figs.

"Gas in Tioga County, Pennsylvania," by S. H. Cathcart and T. H. Myers. *Pennsylvania Topog. and Geol. Survey Bull. 107* (1934). 42 pp., 5 figs.

"Geologic Structure in the Plateau Region of Northern Pennsylvania and Its Relation to the Occurrence of Gas in the Oriskany Sand," by S. H. Cathcart. *Pennsylvania Topog. and Geol. Survey Bull. 108* (Harrisburg, 1934). 24 pp., 2 figs.

"The Possibility of Finding Gas in Cameron County, Pennsylvania," by S. H. Cathcart. *Pennsylvania Topog. and Geol. Survey Bull. 109* (1934). 16 pp., 3 figs.

RUSSIA

"Problems of Soviet Geology," Vol. 1, No. 1 (Moscow, 1934). New Russian publication edited by I. M. Gubkin. Title and table of contents in Russian and English; articles in Russian and summaries in English. This number contains 80 pp., including articles on the 17th International Geological Congress, to be held in Russia; on geotectogenesis; and on the Zayssan syncline. Size, approx. 6.5×9.5 inches. Paper.

TEXAS

"Ground Water in Dimmit and Zavala Counties, Texas," by W. N. White, S. F. Turner, and W. A. Lynch. Prepared with coöperation of *Texas Board of Water Engineers. U. S. Geol. Survey Press Notice 83105* (April 11, 1934). 4 mimeogr. pp. and map showing outcrop of Carrizo sand.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 6 (JUNE, 1934), PP. 831-842

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should sent it promptly to J. P. D. Hull, business manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

George M. Clement, Tyler, Tex.
G. W. Schneider, Shapleigh G. Gray, C. I. Alexander
William Bishop Moore, Houston, Tex.
Angus McLeod, W. Dow Hamm, F. W. Bartlett
Henry Bates Peacock, Dallas, Tex.
R. S. McFarland, E. DeGolyer, C. P. Watson
John McKee Ware, Tulsa, Okla.
Richard B. Rutledge, T. F. Newman, Richard T. Lyons
Frank Smith Westmoreland, Houston, Tex.
Paul B. Hunter, W. Dow Hamm, F. W. Bartlett
Neil Haines Wills, Midland, Tex.
A. L. Ackers, E. A. Wahlstrom, Ronald K. DeFord

FOR ASSOCIATE MEMBERSHIP

Charles Byron Carpenter, Dallas, Tex.
H. B. Hill, F. E. Heath, F. H. Lahee
Charles Edward Ramsey, Oklahoma City, Okla.
Willard L. Miller, Jack M. Copass, John H. Wilson
E. McIver Ross, Jr., Houston, Tex.
John C. Miller, V. E. Monnett, F. C. Sealey
Brame Womack, Dallas, Tex.
E. B. Germany, Sam Aronson, James A. Waters

FOR TRANSFER TO ACTIVE MEMBERSHIP

Cecil Vernon Hagen, Houston, Tex.
Alva C. Ellisor, Byron Rife, L. F. McCollum
Frederick Estill Joekel, Dallas, Tex.
S. A. Thompson, G. E. Green, B. Coleman Renick

Past-presidents of the Association at Dallas, March, 1934.

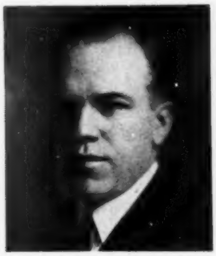
Standing, left to right: Gester, McCoy, Deussen, Gardner, Lahee, Clark, Wrather. *Seated, left to right:* Snyder, Ball, Thomas, DeGolyer, Garrett.

PAST-PRESIDENTS OF THE ASSOCIATION

Thirteen of the fifteen living past-presidents of the Association were present at the nineteenth annual meeting held at Dallas, Texas, March 22–24, 1934. Twelve were photographed in the group shown on the opposite page. Those not included in the group are Wallace E. Pratt and George C. Matson, neither of whom was present at the meeting, and R. S. McFarland, who attended the meeting but was unable to be in the picture. Their individual photographs are here shown.

Wallace C. Pratt

George C. Matson



R. S. McFarland

Only two former presidents are deceased: I. C. White and Sidney Powers. Their photographs are here shown.

I. C. White

Sidney Powers

The chronological list of the past-presidents follows.

PAST-PRESIDENTS OF THE ASSOCIATION[1]

	Term of Office	*Place of Meeting Where Elected*	*Residence When Elected*
J. Elmer Thomas	1917–18	Tulsa, Okla.	Oklahoma
Alexander Deussen	1918–19	Oklahoma City, Okla.	Texas
I. C. White[2]	1919–20	Dallas, Tex.	West Virginia

[1] The name, Southwestern Association of Petroleum Geologists, adopted at Tulsa, Oklahoma, February 9–10, 1917, was changed to The American Association of Petroleum Geologists at Oklahoma City, February 15–16, 1918.

[2] Died, November 25, 1927.

WALLACE E. PRATT	1920–21	Dallas, Tex.	Texas
GEORGE C. MATSON	1921–22	Tulsa, Okla.	Oklahoma
W. E. WRATHER	1922–23	Oklahoma City, Okla.	Texas
MAX W. BALL	1923–24	Shreveport, La.	Colorado
JAMES H. GARDNER	1924–25	Houston, Tex.	Oklahoma
E. L. DEGOLYER	1925–26	Wichita, Kan.	New York
ALEX. W. MCCOY	1926–27	Dallas, Tex.	Colorado
G. C. GESTER	1927–28	Tulsa, Okla.	California
R. S. MCFARLAND	1928–29	San Francisco, Calif.	Oklahoma
J. Y. SNYDER	1929–30	Fort Worth, Tex.	Louisiana
SIDNEY POWERS[3]	1930–31	New Orleans, La.	Oklahoma
L. P. GARRETT	1931–32	San Antonio, Tex.	Texas
FREDERIC H. LAHEE	1932–33	Oklahoma City, Okla.	Texas
FRANK R. CLARK	1933–34	Houston, Tex.	Oklahoma

RESEARCH COMMITTEE

The subject for the research committee's open round-table discussion the Wednesday night before the opening of the annual meeting next March will be: "Migration of Oil, with Special Attention to the Presentation of Cases in Which the Oil Can Be Seen Definitely to Have Migrated or Not to Have Migrated."

The discussion of migration of oil has been extensive but, as far as the chairman of the research committee knows, there has been no attempt to assemble a wide series of specific cases in which the migration or non-migration of oil can be demonstrated.

The suggestion is made that an informal group or groups be formed in each oil center to see what specific cases of fairly definite migration or non-migration of oil can be found in that particular district; and that one or more of the group be prepared to present their findings at the round table of the research committee next March.

DONALD C. BARTON, *chairman*

HOUSTON, TEXAS
May 4, 1934

[3] Died, November 5, 1932.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 6 (JUNE, 1934), PP. 835-841

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

CONSTITUTION AND BY-LAWS

(Adopted 1918 and amended 1921, 1922, 1923, 1925, 1927, 1928, 1929, 1930, 1932, and 1933)

CONSTITUTION

ARTICLE I. NAME

This Association shall be called "The American Association of Petroleum Geologists," incorporated under the laws of Colorado the 21st day of April, 1924, for a period of twenty (20) years.

ARTICLE II. OBJECT

The object of this Association is to promote the science of geology, especially as it relates to petroleum and natural gas; to promote the technology of petroleum and natural gas and to encourage improvements in the methods of exploring for and exploiting these substances; to foster the spirit of scientific research amongst its members; to disseminate facts relating to the geology and technology of petroleum and natural gas; to maintain a high standard of professional conduct on the part of its members; and to protect the public from the work of inadequately trained and unscrupulous persons posing as petroleum geologists.

ARTICLE III. MEMBERSHIP

Members

SECTION 1. Any person engaged in the work of petroleum geology or in research pertaining to petroleum geology or technology is eligible to active membership, provided he is a graduate of an institution of collegiate standing, in which institution he has done his major work in geology, or in sciences fundamental to petroleum geology, and in addition has had the equivalent of three years' experience in petroleum geology or in the application of these other sciences to petroleum geology or to research in petroleum geology or technology; and provided further that in the case of an applicant for membership who has not had the required collegiate or university training, but whose standing in the profession is well recognized, he shall be admitted to membership when his application shall have been favorably and unanimously acted upon by the executive committee; and provided further that these requirements shall not be construed to exclude teachers and research workers in recognized institutions, whose work is of such character as in the opinion of the executive committee shall qualify them for membership.

Active members alone shall be known as members.

Life Members

SECTION 2. The executive committee may grant life membership to members who have paid their dues and are otherwise qualified.

Associates

SECTION 3. Any person having completed as much as thirty hours of geology (an hour shall here be interpreted as meaning as much as sixteen recitation or lecture periods of one hour each, or the equivalent in laboratory) in a reputable institution of collegiate or university standing, or who has done field work equivalent to this, is eligible to associate membership, provided at the time of his application for membership he shall be engaged in geological studies in an institution of collegiate or university standing, or shall be engaged in petroleum geology; and any person who is a graduate of an institution of collegiate standing in which he has done his major work in sciences fundamental to petroleum geology or petroleum technology, and who has the equivalent of one year's experience in the application of his science to the study of petroleum geology, shall be eligible to associate membership, provided at the time of his application for membership he shall be engaged in investigations in the broader subject of petroleum geology and technology.

Associate members shall be known as associates.

Associates shall enjoy all the privileges of membership in the Association, save that they shall not hold office, sign applications for membership, or vote; neither shall they have the privilege of advertising their affiliation with the Association in professional cards or professional reports or otherwise.

The executive committee may advance to active membership, without the formality of application for such change, those associates who have, subsequent to election, fulfilled the requirements for active membership.

Election to Membership

SECTION 4. Every candidate for admission as a member or associate shall submit a formal application on an application form authorized by the executive committee, signed by him, and endorsed by not less than three members who are in good standing, stating his training and experience and such other facts as the executive committee shall from time to time prescribe. Provided the executive committee, after due consideration, shall judge that the applicant's qualifications meet the requirements of the constitution, they shall cause to be published in the *Bulletin* the applicant's name and the names of his sponsors. If, after at least thirty days have elapsed since such publication, no reason is presented why the applicant should not be admitted, he shall be deemed eligible to membership or to associate membership, as the case may be, and shall be notified of his election.

SECTION 5. An applicant for membership, on being notified of his election in writing, shall pay full membership dues for the current year and on making such payment shall be entitled to receive the entire *Bulletin* for that year. Unless payment of dues is made within thirty (30) days by those living within the continental United States and within ninety (90) days by those living elsewhere, after notice of election has been mailed, the executive committee may rescind the election of the applicant. Upon payment of dues, each applicant for membership shall be furnished with a membership card for the cur-

rent year, and until such written notice and card are received, he shall in no way be considered a member of the Association.

Honorary Members

SECTION 6. The executive committee may from time to time elect as honorary members persons who have contributed distinguished service to the cause of petroleum geology. Honorary members shall not be required to pay dues.

ARTICLE IV. OFFICERS AND THEIR DUTIES

Officers

SECTION 1. The officers of the Association shall be a president, a vice-president, a secretary-treasurer, and an editor. These, together with the past president, shall constitute the executive committee and managers of the Association.

SECTION 2. The officers shall be elected annually from the Association at large by written ballot deposited in a locked ballot box by those members, present at the annual meeting, who have paid their current dues and are otherwise qualified under the constitution. Each candidate, when voted for as a candidate for the particular office for which he is nominated, shall be thereby automatically voted for as a candidate for the executive committee for one year, except that candidates for the presidency shall be automatically voted for as candidates for the executive committee for two years.

SECTION 3. No one shall hold the office of president for two consecutive years and no one shall hold any other office for more than two consecutive years except the editor who shall not hold office for more than six consecutive years.

Duties of Officers

SECTION 4. The president shall be the presiding officer at all meetings of the Association, shall take cognizance of the acts of the Association and of its officers, shall appoint such committees as are required for the purposes of the Association, and shall delegate members to represent the Association. He may, at his option, serve on, and may be chairman of, any committee.

SECTION 5. The vice-president shall assume the office of president in case of a vacancy from any cause in that office and shall assume the duties of president in case of the absence or disability of the latter.

SECTION 6. The secretary-treasurer shall assume the duties of president in case of the absence of both the president and vice-president. He shall have charge of the financial affairs of the Association and shall annually submit reports as secretary-treasurer covering the fiscal year. He shall receive all funds of the Association, and, under the direction of the executive committee, shall disburse all funds of the Association. He shall cause an audit to be prepared annually by a public accountant at the expense of the Association. He shall give a bond, and shall cause to be bonded all employees to whom authority may be delegated to handle Association funds. The amount of such bonds shall be set by the executive committee and the expense shall be borne by the Association. The funds of the Association shall be disbursed by check as authorized by the executive committee.

SECTION 7. The editor shall be in charge of editorial business, shall submit an annual report of such business, shall have authority to solicit papers and

material for the *Bulletin* and for special publications, and, with the approval of the executive committee, may accept or reject material offered for publication. He may appoint associate, regional, and special editors.

SECTION 8. The officers shall assume the duties of their respective offices immediately after the annual meeting in which they are elected.

ARTICLE V. EXECUTIVE COMMITTEE—MEETINGS AND DUTIES

Executive Committee

SECTION 1. The executive committee shall consist of the president, past president, vice-president, secretary-treasurer, and editor.

Meetings and Duties

SECTION 2. The executive committee shall meet immediately preceding the annual meeting and at the call of the president may hold meetings when and where thought advisable, to conduct the affairs of the Association. A joint meeting of the outgoing and incoming executive committees shall be held immediately after the close of the annual Association business meeting. Members of the executive committee may vote by proxy on matters which require a unanimous vote.

SECTION 3. The executive committee shall consider all nominations for membership and pass on the qualifications of the applicants; shall have control and management of the affairs and funds of the Association; shall determine the manner of publication and pass on the material presented for publication; and shall designate the place of the annual meeting. They are empowered to establish a business headquarters for the Association, and to employ such persons as are needed to conduct the business of the Association. They are empowered to accept, create, and maintain special funds for publication, research, and other purposes. They are empowered to make investments of both general and special funds of the Association. Trust funds may be created giving to the trustees appointed for such purpose such discretion as to investments as seems desirable to the executive committee to accomplish any of its objects and purposes, but no such trust funds shall be created unless they are revocable upon ninety (90) days' notice.

ARTICLE VI. MEETINGS

The Association shall hold at least one stated meeting each year, which shall be the annual meeting. This meeting shall be held in March at a time and place designated by the executive committee. At this meeting the election of members shall be announced, the proceedings of the preceding meeting shall be read, Association business shall be transacted, scientific papers shall be read and discussed, and officers for the ensuing year shall be elected.

ARTICLE VII. AMENDMENTS

Amendments to this constitution may be proposed by a resolution of the executive committee, by a constitutional committee appointed by the president, or in writing by any ten members of the Association. All such resolutions or proposals must be submitted at the annual meeting of the business committee of the Association as provided in the by-laws, and only the business committee shall make recommendations concerning proposed constitutional changes at the annual Association business meeting. If such recommendations by the business committee shall be favorably acted on at the annual Associa-

tion business meeting, the secretary-treasurer shall arrange for a ballot of the membership by mail within thirty (30) days after said annual Association business meeting, and a majority vote of the ballots received within ninety (90) days of their mailing shall be sufficient to amend. The legality of all amendments must be determined by the executive committee prior to balloting.

BY-LAWS

ARTICLE I. DUES

SECTION 1. The fiscal year of the Association shall correspond with the calendar year.

SECTION 2. The annual dues of members of the Association shall be twelve dollars ($12.00). The annual dues of associates for not to exceed six years after election shall be eight dollars ($8.00); thereafter, the annual dues of such associates shall be twelve dollars ($12.00). The annual dues are payable in advance on the first day of each calendar year. A bill shall be mailed to each member and associate before January first of each year, stating the amount of the annual dues and the penalty and conditions for default in payment. Members or associates who shall fail to pay their annual dues by April first shall not receive copies of the April *Bulletin* or succeeding *Bulletins*, nor shall they be privileged to buy Association special publications at prices made to the membership, until such arrears are met.

SECTION 3. On the payment of three hundred dollars ($300.00) any member in good standing shall be declared a life member and thereafter shall not be required to pay annual dues. The funds derived from this source shall be placed in a permanent investment, the income from which shall be devoted to the same purposes as the regular dues.

ARTICLE II. RESIGNATION—SUSPENSION—EXPULSION

SECTION 1. Any member or associate may resign from the Association at any time. Such resignation shall be in writing and shall be accepted by the executive committee, subject to the payment of all outstanding dues and obligations of the resigning member or associate.

SECTION 2. Any member or associate who is more than a year delinquent (in arrears) in payment of dues shall be suspended from the Association. Any delinquent or suspended member or associate, at his own option, may request in writing that he be dropped from the Association and such request shall be granted by the executive committee. Any member or associate more than two years in arrears shall be dropped from the Association. The time of payment of delinquent dues for either one year or two years may be extended by an unanimous vote of the executive committee.

SECTION 3. Any member or associate who resigns or is dropped under the provisions of sections 1 and 2 of this article ceases to have any rights in the Association and ceases to incur further indebtedness to the Association.

SECTION 4. Any person who has ceased to be a member or associate under Section 1 or Section 2 of this article may be reinstated by a unanimous vote of the executive committee subject to the payment of any outstanding dues and obligations which were incurred, prior to the date when he ceased to be a member or associate of the Association.

SECTION 5. Any member or associate who, after being granted a hearing by the executive committee, shall be found guilty of a violation of the code of

ethics of this Association or shall be found guilty of a violation of the established principles of professional ethics, or shall be found guilty of having made a false or misleading statement in his application for membership in the Association, may be suspended or expelled from the Association by a unanimous vote of the executive committee. The decision of the executive committee in all matters pertaining to the interpretation and execution of the provisions of this section shall be final.

ARTICLE III. PUBLICATIONS

SECTION 1. The proceedings of the annual meeting and the papers presented at such meeting shall be published at the discretion of the executive committee in the Association *Bulletin* or in such other form as the executive committee may decide best meets the needs of the membership of the Association.

SECTION 2. The payment of annual dues for any fiscal year entitles the member or associate to receive without further charge a copy of the *Bulletin* of the Association for that year.

SECTION 3. The executive committee may authorize the printing of special publications to be financed by the Association from its general, publication, or special funds and offered for sale to members and associates in good standing at not less than the cost of publication and distribution.

ARTICLE IV. REGIONAL SECTIONS, TECHNICAL DIVISIONS, AND AFFILIATED SOCIETIES

SECTION 1. Regional sections of the Association may be established provided the members of such sections are members of the Association and shall perfect an organization and make application to the executive committee. The executive committee shall submit the application to a vote at a regular annual meeting, an affirmative vote of two-thirds of the members present and voting being necessary for the establishment of such a section; and provided that the Association may revoke the charter of any regional section by a vote of two-thirds of the members present and voting at a regular annual meeting.

SECTION 2. Technical divisions may be established, provided the members interested shall perfect an organization and make application to the executive committee. The executive committee shall submit the application to a vote at a regular meeting, an affirmative vote of two-thirds of the membership present and voting being necessary for the establishment of such a division. In like manner, the Association may dissolve a division by an affirmative vote of two-thirds of the members present and voting at any annual meeting. A technical division may have its own officers and it may have its own constitution and by-laws provided that, in the opinion of the executive committee, these do not conflict with the constitution and by-laws of the Association. The executive committee shall be empowered to make arrangements with the officers of the division for the conduct of the business of the division. A division may admit to affiliate membership in the division specially qualified persons who are not eligible to membership in the Association. Technical divisions may affiliate with other scientific societies, with the approval of the executive committee.

SECTION 3. Subject to the affirmative vote of two-thirds of the membership present and voting at an annual meeting, and with legal advice, the executive committee may arrange for the affiliation with the Association of duly

organized groups or societies, which by object, aims, constitution, by-laws, or practice are developing the study of geology or petroleum technology. In like manner and with like advice, the executive committee may arrange conditions for dissolution of such affiliations. Affiliation with the Association need not prevent affiliation with other scientific societies. Members of affiliated societies who are not members of the Association, shall not have the privilege of advertising their affiliation with the Association on professional cards or otherwise.

ARTICLE V. DISTRICT REPRESENTATIVES

The executive committee shall cause to be elected district representatives from districts which it shall define by a local geographic grouping of the membership. Such districts shall be redesignated and redefined by the executive committee as often as seems advisable. Each district shall be entitled to one representative for each seventy-five members, but this shall not deprive any designated district of at least one representative. The representatives so apportioned shall be chosen from the membership of the district by a written ballot arranged by the executive committee. They shall hold office for two years, their term of office expiring at the close of the annual meeting.

ARTICLE VI. BUSINESS COMMITTEE

There shall be a business committee to act as a council and advisory board to the executive committee and the Association. This committee shall consist of the executive committee, not more than five members at large appointed by the president, two members elected by and from each technical division, and the district representatives. The president shall also appoint a chairman and a vice-chairman, but neither of these need be one of those otherwise constituting the business committee. The secretary-treasurer shall act as secretary of the business committee. If a district or technical representative is unable to be present at any meeting of the committee he may designate an alternate, who, in the case of a district representative, may or may not be a resident of the district he is asked to represent, and the alternate, on presentation of such a designation in writing, shall have the same powers and privileges as a regularly chosen representative. The business committee shall meet the day before the annual meeting at which time all proposed changes in the constitution or by-laws shall be considered, all old and new business shall be discussed, and recommendations shall be voted for presentation at the annual meeting.

ARTICLE VII. AMENDMENTS

These by-laws may be amended by vote of three-fourths of the members present and voting at any annual meeting, provided that such changes shall have been recommended to the meeting by the business committee and provided that their legality shall be determined by the executive committee prior to publication.

ASSOCIATION COMMITTEES

EXECUTIVE COMMITTEE

William B. Heroy, *chairman*, New York, N. Y.
M. G. Cheney, *secretary*, Coleman, Texas
Frank R. Clark, Tulsa, Oklahoma
Edwin B. Hopkins, Dallas, Texas
L. C. Snider, New York, N. Y.

GENERAL BUSINESS COMMITTEE

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Arthur A. Baker (1936)
R. A. Birk (1936)
M. G. Cheney (1935)
Frank R. Clark (1935)
H. E. Crum (1935)
C. L. Dake (1935)
E. F. Davis (1936)
Joseph A. Dawson 1935)
C. E. Dobbin (1935)
James Terry Duce (1935)
H. B. Fuqua (1935)
M. W. Grimm (1935)
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Edgar Kraus (1935)
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Theodore A. Link (1935)
R. T. Lyons (1935)
Roy G. Mead (1935)
A. F. Morris (1935)
L. Murray Neumann (1936)
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A. L. Selig (1935)
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Paul Weaver (1935)
Maynard P. White (1935)
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C. V. Millikan (1935)
L. C. Snider (1935)
L. C. Uren (1935)
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R. S. Knappen (1936)
W. C. Spooner (1936)
Parker D. Trask (1936)

REPRESENTATIVE ON DIVISION OF GEOLOGY AND GEOGRAPHY NATIONAL RESEARCH COUNCIL

R. S. Knappen (1934)

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John G. Bartram
M. G. Cheney
Alexander Deussen
B. F. Hake
G. D. Hanna
A. I. Levorsen
C. L. Moody
R. C. Moore
Ed. W. Owen

TRUSTEES OF REVOLVING PUBLICATION FUND

Frank R. Clark (1935)
Charles H. Row (1936)

TRUSTEES OF RESEARCH FUND

Alex. W. McCoy (1935)
Robert H. Dott (1936)

FINANCE COMMITTEE

W. E. Wrather (1935)
Joseph E. Pogue (1936)

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William H. Atkinson
Donald C. Barton
Ford Bradish
Arthur E. Brainerd
H. A. Buehler
Hal P. Bybee
Herschel H. Cooper
Carey Croneis
Marvin Lee
S. E. Slipper
E. K. Soper
Luther H. White
R. B. Whitehead

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 18, NO. 6 (JUNE, 1934), PP. 843-846

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

J. O. NOMLAND, of the geological staff of the Standard Oil Company of California, San Francisco, has spent several months in the new oil field of the company at Bahrein Island, Persian Gulf, and on the newly acquired concession of the California-Arabian Standard Oil Company in northeastern Arabia.

E. H. FINCH has changed his address from the Auditorium Hotel, Houston, Texas, to 926 Merida Street, Route 5, Box 145-M, San Antonio, Texas.

J. C. FINLEY, geologist with Phillips Petroleum Company, has been transferred from Shawnee, to Bartlesville, Oklahoma.

ANDREW C. WRIGHT has changed his address from Box 295, Rockdale, Texas, to 2120 Sul Ross Avenue, Houston, Texas.

ARTHUR R. FOSDICK, formerly of 706 Fort Worth National Bank Building, Fort Worth, Texas, is now at Box 459, Houston, Texas.

RODERICK A. STAMEY, formerly with the Texas Gulf Producing Company, has an office at 1716-17 Esperson Building, Houston, Texas, as consulting geologist and paleontologist.

A. ALLEN WEYMOUTH is now stationed at Bahrein Island, Persian Gulf, as micropaleontologist for the Bahrein Petroleum Company, a subsidiary of the Standard Oil Company of California.

W. I. INGHAM completed his Master's degree in geology at the Colorado School of Mines last February, and is now employed with The Texas Oil Company as subsurface geologist, with headquarters at Houston, Texas.

WILLIAM A. CLARK, JR., has changed his address from Box 24, Livingston, Texas, to 5820 Charlotte, Houston, Texas.

ROBERT E. KING, formerly of Box 427, Iowa City, Iowa, may now be addressed at 2424 Fredericksburg Road, San Antonio, Texas.

E. G. ALLEN may be addressed at 4015 University Boulevard, Dallas, Texas.

W. C. KNEALE, geologist for The Texas Company, has been transferred from Fort Worth to Wichita Falls, Texas.

C. L. MOHR, district geologist for the Indian Territory Illuminating Oil Company, San Angelo, Texas, has been transferred to the new company office at San Antonio, Texas, to carry on in the same capacity.

SIDNEY A. JUDSON, of the Texas Gulf Production Company, Houston, Texas, addressed the April meeting of the Shreveport Geological Society on "Segmentation of Flank Sands of Salt Domes by Radial Faulting."

The Tulsa Stratigraphic Society has elected the following officers for the year 1934–35: president, ROBERT M. WHITESIDE, Shell Petroleum Corporation, Tulsa; vice-president, RONALD L. CULLEN, Twin State Oil Company, Tulsa; and secretary-treasurer, JOSEPH L. BORDEN, The Pure Oil Company, Tulsa.

WILLIAM F. LOWE, geologist and engineer, with *National Petroleum News* since 1929, has been elected secretary-treasurer of the Natural Gasoline Association of America, succeeding RAY E. MILLER.

ADDISON YOUNG has changed his address from Rio Grande City, to Box 1605, Midland, Texas.

At a meeting of the Tulsa Geological Society, Monday, May 7, GLENN GRIMES, of the Wirt Franklin Petroleum Corporation, Oklahoma City, spoke on "The Tatums Pool, Oklahoma," and FANNY C. EDSON, of the Shell Petroleum Corporation, Tulsa, spoke on "The Sooy Conglomerate of Kansas."

E. H. BARBOUR has retired as head of the department of geology at the University of Nebraska, after 43 years of continuous service in that capacity. He will continue as director of the university museum and as professor of paleontology. E. F. SCHRAMM, who has been a member of the geology staff since 1908 and professor of geology since 1918, has succeeded as head of the department. A. L. LUGN, a member of the staff since 1927, has been promoted from assistant professor to associate professor of geology.

G. C. SIVERSON is district geologist for the Tidewater Oil Company at the Tulsa office.

T. E. WEIRICH is now on the geological staff of the Phillips Petroleum Company of Bartlesville, Oklahoma.

R. B. ROARK, of the Shell Petroleum Corporation, Tulsa, returns this month from The Hague, after several months in Europe.

R. A. STEINMAYER, of the geology department of Tulane University, New Orleans, presented a paper, "Origin, Development, and Bottom Sediments of Lake Ponchartrain," before the Shreveport Geological Society at its May meeting.

RICHARD W. SMITH, State Capitol, Atlanta, is state geologist of Georgia.

W. ROSS KEYTE is with Dowell Incorporated as sales and service engineer in the Oklahoma district.

GEORGE EDWIN DORSEY, of Dallas, Texas, chief geologist for the Magnolia Petroleum Company, has been in the New York Office of the company for several months.

W. W. ORCUTT, vice-president of the Union Oil Company, Los Angeles, and an honorary member of the Association, lost his left arm in a recent automobile accident. He has completed 36 years in the service of the company.

The North Texas Geological Society sponsored a trip under the guidance of FRANK GOUIN, of Duncan, Oklahoma, into Clay County, Texas, and adjacent areas June 8–9 to study the Permian-Pennsylvanian contact.

At the regular monthly meeting of the San Antonio Geological Society, Monday evening, June 4, H. N. SEEVERS, district geologist for the Atlantic Oil Producing Company, at Corpus Christi, Texas, presented a paper on "The Greta Field."

The Second Annual Petroleum Conference of Illinois, sponsored by the Illinois-Indiana Petroleum Association and the Illinois State Geological Survey, was held on June 1, 1934, at the Crawford County Country Club, Robinson, Illinois. The following papers were on the program: "Air Repressuring in the Colmar-Plymouth Oil Field," M. H. FLOOD; "Natural Floods in Illinois Oil Fields," A. H. BELL; "Accidental Floods in Illinois Oil Fields," FREDERICK SQUIRES; "Recent Results in Controlled Water-Flooding," W. S. CORWIN; "Acid Treatment of Oil Wells in Lime Formations," P. E. FITZGERALD; "Possible Areas for Acid Treatment in Illinois," A. H. Bell; "Electric Condenser Process for Dehydration of Crude Oil," R. J. PIERSOL; "The Function of Research in the Discovery and Production of Petroleum," M. M. LEIGHTON.

J. S. HUDNALL, of Tyler, Texas, addressed the Fort Worth Geological Society on May 14, his subject being "Volume Changes in the East Texas Oil Field Due to the Compressibility of the Reservoir Rocks."

ROBERT ROTH is now connected with the Humble Oil and Refining Company in Wichita Falls, Texas.

The committee on nomenclature of new pools of the Houston Geological Society has designated the following names for new producing areas which have been accepted and approved by the Houston Geological Society. The area in northern Liberty County, in the vicinity of Cleveland, is designated as the Cleveland pool. The area in southeastern Montgomery County, in vicinity of the town of Splendora, has been designated as the Splendora pool. The area in southwestern Jackson County, in the vicinity of the town of Vanderbilt, around the newly discovered Encino Toney No. 1, has been designated as Vanderbilt pool.

The Tulsa Geological Society held its annual baseball game, picnic, and dance at Mohawk Park, May 25.

CHESTER CASSEL has been made assistant chief geologist for The Texas Company (California).

LESLIE S. HARLOWE is employed by Oil Production, Inc., and the C. M. Leonard interest in production, land, and geological work. He is moving from Overton, Texas, to Shreveport, Louisiana, where his address is 325 First National Bank Building.

GEORGE R. STEVENS, consulting geologist of Shreveport, Louisiana, has been in western Colorado recently investigating mining properties.

EARL TRAGER is chief of the Naturalist Division of the Branch of Research and Education for the National Park Service at Washington, D.C.

A field party of the United States Geological Survey under the direction of C. H. DANE is conducting an investigation of the coal and gas resources of an area north of the McAlester district and south of Canadian River in eastern Oklahoma as a field project under the Federal Emergency Administration of Public Works. The party includes J. S. Williams, Carl B. Anderson, H. E. Rothrock, L. M. Wilshire, Raymond Hart, and Walton Christian.

RAE PREECE, formerly with the Devonian Oil Company, is now on the geological staff of the Darby Petroleum Corporation at San Antonio, Texas.

FRANK GOUIN, of Duncan, Oklahoma, talked to the North Texas Geological Society on the subject of "Geology and Oil Possibilities of Southern Oklahoma" on the evening of May 11, 1934.

CHESTER W. WASHBURNE lectured on "Faulting" at the University of Chicago, the University of Michigan, and Northwestern University, in May.

H. B. GOODRICH, L. E. KENNEDY, R. C. BECKSTRON, H. D. JENKINS' J. H. HENGST, W. R. DILLARD, J. N. CONLEY, J. G. BEAULEIU, recently employed by the United States Geological Survey, are working with N. W. BASS on a subsurface geologic study of the Osage, Ponca, and Kaw Indian reservations, Oklahoma.

JOHN B. LUCKE has been appointed geologist for The Texas Company and is stationed in the Panhandle district. He may be addressed at Box 1221, Pampa, Texas.

SELDON D. BUTCHER has opened his headquarters office in the Esperson Building, Houston, Texas, to continue consulting and geological work.

The San Antonio Geological Society held its annual baseball game and picnic at Landa Park, New Braunfels, Texas, June 2.

H. C. GEORGE, head of the department of oil and gas production at the University of Pittsburgh, has an article on "Development of Technical Education for the Petroleum Industry," in the June issue of *Mining and Metallurgy*.

The Association research committee, DONALD C. BARTON, chairman, held a meeting at Tulsa on May 19 in connection with the 8th International Petroleum Congress. The general subject for discussion was "Geological Changes in Petroleum Reservoirs Affecting Discovery." C. V. MILLIKAN, of the Amerada Petroleum Corporation, was chairman of the meeting.

BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

OFFICE OF PUBLICATION, 505 TULSA BUILDING, TULSA, OKLAHOMA

THE BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS is published by the Association on the 15th of each month. Editorial and publication office, 505 Tulsa Building, Tulsa, Oklahoma, Post Office Box 1852. Cable address, AAPGEOL.

THE SUBSCRIPTION PRICE to non-members of the Association is $15.00 per year (separate numbers $1.50) prepaid to addresses in the United States. For addresses outside the United States, an additional charge of $0.40 is made on each subscription to cover extra wrapping and handling.

British agent: Thomas Murby & Co., 1 Fleet Lane, Ludgate Circus, London, E. C. 4.

German agent: Max Weg, Königstrasse 3, Leipzig, Germany.

CLAIMS FOR NON-RECEIPT of preceding numbers of the BULLETIN must be sent to the business manager within three months of the date of publication in order to be filled gratis.

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Association Headquarters—505 Tulsa Building, East Fifth Street at Cincinnati Avenue, Tulsa, Oklahoma.

Communications about the Bulletin, manuscripts, editorial matters, subscriptions, special rates to public and university libraries, publications, membership, change of address, advertising rates, and other Association business should be addressed to

J. P. D. HULL, *Business Manager*

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

BOX 1852

TULSA, OKLAHOMA

Entered as second-class matter at the Post Office of Tulsa, Oklahoma, and at the Post Office at Menasha Wisconsin, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized March 9, 1923.

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

OFFICERS FOR THE YEAR ENDING MARCH, 1935

WILLIAM B. HEROY, *President*, New York, N. Y.
EDWIN B. HOPKINS, *Vice-President*, Dallas, Texas
M. G. CHENEY, *Secretary-Treasurer*, Coleman, Texas
L. C. SNIDER, *Editor*, New York, N. Y.

(The foregoing officers, together with the *Past-President*, FRANK RINKER CLARK, Tulsa, Oklahoma, constitute the Executive Committee.)

DISTRICT REPRESENTATIVES

(Representatives' terms expire immediately after annual meetings of the years shown in parentheses)

Amarillo: ——————, Amarillo, Tex.
Appalachian: H. E. Crum (35), Charleston, W. Va.
Canada: Theodore A. Link (35), Calgary, Canada
Capitol: Arthur A. Baker (36), Washington, D. C.
Dallas: Sam M. Aronson (36), Dallas, Tex.
East Oklahoma: R. T. Lyons (35), Tulsa, Okla; A. F. Morris (35), Bartlesville, Okla.; L. Murray Neumann (36), Tulsa, Okla.
Fort Worth: H. B. Fuqua (35), Fort Worth, Tex.
Great Lakes: C. L. Dake (35), Rolla, Mo.
Houston: Paul Weaver (35), Houston, Tex.
Mexico: S. A. Grogan (35), Tampico, Mexico
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New York: James Terry Duce (35) New York, N. Y.
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Rocky Mountains: C. E. Dobbin (35), Denver, Colo.
San Antonio: Joseph M. Dawson (35), San Antonio, Tex.
Shreveport: M. W. Grimm (35), Shreveport, La.
South America: Philip E. Nolan (35), Maracaibo, Venezuela
So. Permian Basin: John F. Hosterman (35), San Angelo, Tex.
Tyler: Wallace C. Thompson (35), Tyler, Tex.
West Oklahoma: Roland W. Laughlin (35), Oklahoma City, Okla.
Wichita: E. A. Wyman (35), Wichita, Kan.
Wichita Falls: R. A. Birk (36), Wichita Falls, Tex.

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Maynard P. White (35), Ardmore, Okla.

Geophysics

O. C. Lester, Jr. (35), Tulsa, Okla.
A. L. Selig (35), Fort Worth, Tex.

PACIFIC SECTION (Chartered, March, 1925)

A. A. CURTICE, *President*, 435 A. G. Bartlett Building, Los Angeles, California
WILBUR D. RANKIN, *Secretary-Treasurer*, 1121 Subway Terminal Building, Los Angeles, California

Membership restricted to members of the Association in good standing, residing in Pacific Coast states. Dues: $1.00 per year

SAN ANTONIO SECTION (Chartered, April, 1929)

T. J. GALBRAITH, *President*, The California Company, San Antonio, Texas
T. R. BANKS, *Secretary-Treasurer*, Magnolia Petroleum Company, San Antonio, Texas

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MARACAIBO SECTION (Chartered, April, 1930)

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CHESTER A. BAIRD, *Secretary-Treasurer*, Venezuela Gulf Oil Company, Maracaibo, Venezuela

DIVISION OF PALEONTOLOGY AND MINERALOGY
SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

(Affiliated, March, 1928; chartered, technical division, April, 1930)

NORMAN L. THOMAS, *President*, Fort Worth, Texas
GAYLE SCOTT, *Secretary-Treasurer*, Texas Christian University, Fort Worth, Texas

The Society issues a quarterly, the *Journal of Paleontology*, Raymond C. Moore, editor, University of Kansas, Lawrence, Kansas: subscription, $6.00. Society dues (including subscription to *Journal*), $6.00. A remission of $2.00 is allowed on dues of members or associate members of the Association.

DIVISION OF GEOPHYSICS
SOCIETY OF PETROLEUM GEOPHYSICISTS

(Chartered, technical division, April, 1932)

E. E. ROSAIRE, *President*, Houston, Texas
BELA HUBBARD, *Secretary-Treasurer*, Carter Oil Company, Tulsa, Oklahoma

AFFILIATED SOCIETIES

(Dates of affiliation in parentheses)

Alberta Society of Petroleum Geologists, Calgary, Alberta, Canada (31). E. J. P. van der Linden, Secy., 215 First Ave., N. E.
Appalachian Geological Society, Charleston, West Virginia (31). Robert C. Lafferty, Secy., Columbian Carbon Company
East Texas Geological Society, Tyler, Texas (32). F. H. Schouten, Secy., Stanolind Oil and Gas Company
Fort Worth Geological Society, Fort Worth, Texas (31). Thomas B. Romine, Secy., Box 2110, Texas Pacific Coal and Oil Co.
Houston Geological Society, Houston, Texas (32). John C. Miller, Secy., The Texas Company
Kansas Geological Society, Wichita, Kansas (31). Howard S. Bryant, Secy., Skelly Oil Company
Midland Geological Society, Midland, Texas (31). Alden S. Donnelly, Secy., Honolulu Oil Company
Oklahoma City Geological Society, Oklahoma City, Oklahoma (31). Clarence M. Sale, Secy., Magnolia Petroleum Company
Panhandle Geological Society, Amarillo, Texas (32). Earle N. Armstrong, Secy., 3902 Cheyenne Road
Shawnee Geological Society, Shawnee, Oklahoma (31). Ray Youngmeyer, Secy., Amerada Petroleum Corporation, Box 896
Shreveport Geological Society, Shreveport, Louisiana (32). G. D. Thomas, Secy., Shell Petroleum Corporation
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BULLETIN
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